THE POST-TERTIARY DEPOSITS

OF

CAMBRIDGESHIRE,

BEING

The Sedgwick Prize Essay

FOR 1876.

BY

A. J. JUKES-BROWNE, B.A., F.G.S.,

OF ST JOHN'S COLLEGE, CAMBRIDGE, AND H.M. GEOLOGICAL SURVEY.

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PREFACE.

THE subject proposed for the Sedgwick Essay in 1876 was "The Post-tertiary deposits of Cambridgeshire and their relations to deposits of the same period in the rest of East Anglia."

Circumstances have prevented the earlier publication of this Essay, to which the prize was awarded; but the delay has enabled me to make a few additions to the original manuscript, such supplemental matter being indicated by the use of square brackets in the text. With the exception of this and of the concluding remarks, the Essay is now printed in the same form in which it was sent to the Adjudicators of the prize.

I am indebted to the Director of the Geological Survey of England for permission to make use of the information obtained during the survey of that part of Cambridgeshire on which I was engaged at the time the Essay was written. My thanks are also due to my colleagues, Mr W. H. Penning and Mr S. B. J. Skertchly, for the notes relating to other parts of the county which they placed at my disposal.

A. J. JUKES-BROWNE.

5 WEST HILL, HIGHGATE,
July, 1878.

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CHAPTER I.

INTRODUCTORY.

THE existence of a series of deposits and accumulations, intervening between the vegetable soil and the older strata of the earth's crust, has long been known to Geologists; they rest indiscriminately on formations of Tertiary, Secondary or Primary age, and they form what farmers call the sub-soil over large portions of those districts in the British Islands which have been brought under cultivation. Notwithstanding, however, their importance from an agricultural point of view, these superficial deposits were little studied in the early days of Geology, and the first endeavours to account for their occurrence were very crude and unsatisfactory; it is only indeed within the last 20 or 25 years that they have received that amount of attention which they merited, and only within the last 10 or 12 that Geologists have been able to give anything like an adequate and comprehensive account of their distribution and mode of formation.

By the Huttonians these deposits were all classed together, and regarded as the result of atmospheric action and fluviatile erosion on the surface of the continents during a long lapse of ages. The possibility of separating them into two groups or series, differing in their constitution and mode of occurrence, was first indicated by Cuvier in the Preface to his work on "Fossil Quadrupeds" at the close of the last century (1798). In this preliminary essay, now known under the name of "Cuvier's Theory of the Earth," (which was translated into English in 1813) he speaks of the beds forming the Paris basin as surmounted by various *alluvial deposits*. He notices that some

of these contain mammalian remains belonging to extinct species, while "the bones of species apparently identical with those now living are never found except in the very latest alluvia;" these deposits he describes as resulting from causes now in operation, but believes this present state of affairs to have been preceded by a great catastrophe or deluge.

Referring to this supposition in a paper read before the Geological Society in the year 1819, Dr Buckland says—"For the purpose of impressing more strongly this distinction which I have drawn between *diluvian* and *post-diluvian* gravels, it will be convenient if Geologists will consent to restrict the term *diluvium* to the superficial gravel-beds produced by the last universal deluge; and designate by the term *alluvium* those local accumulations that have been formed since that period," by the action of torrents and other causes in daily operation.

In 1823 Dr Buckland published his *Reliquiæ Diluvianæ*, and developing more fully his hypothesis that the diluvial deposits were produced by the waters of the Mosaic Deluge, he gave a fresh importance and signification to the terms Diluvium and Alluvium.

The nomenclature thus proposed by Prof. Buckland was for many years accepted and made use of by Geologists, and it required a long series of close and accurate observations completely to dispel the false ideas and analogies with which this terminology had invested the subject. The principle of the classification however was a sound one, and the original distinction between those formations which originated "in a former and different order of things," and those which have resulted from causes still in operation, has in fact become more clear and defined in the progress of Geological knowledge.

Thus we find Prof. Sedgwick contributing two papers "On the Origin of Alluvial and Diluvial Formations" to the *Annals of Philosophy* for 1835, in which he points out that the Diluvial deposits occur with different characters and generally at different elevations from the Alluvial, but that where both are present the latter always rest on the former, and that they belong therefore to distinct epochs.

The Diluvial formations he divides into two classes:—"The first composed of coarse materials often lodged at considerable

elevations and apparently drifted into their present position by the first rush of waters; the second generally found at lower elevations and apparently comminuted by the continued attrition of the retiring waters." As he refers to this latter class of deposits the gravels which are found between Cambridge and Lynn, and which are clearly river-gravels of Post-glacial date, it is evident that the Diluvial and Alluvial formations did not accurately correspond with what are now known as the Glacial and Post-glacial deposits.

It is necessary to remember this while perusing the older papers written on the subject; and we may perhaps correlate the old and new nomenclature as follows:—

Diluvial Detritus	Older division = Glacial Deposits.	
	Newer division = Older Valley-gravels.	Post-glacial Deposits.
Alluvial Detritus	= Newer Valley-gravels and Alluvium.	

It soon began to be felt, however, that the formation of the deposits grouped under the head of Diluvial Detritus could not be attributed to one and the same set of agencies, and in his Anniversary Address to the Geological Society in 1831, Prof. Sedgwick observes that "we ought to have paused before we adopted the Diluvian theory and referred all our old superficial gravels to the action of the Mosaic flood....Bearing upon this difficult question there is I think one great negative conclusion now incontestably established—that the vast masses of diluvial gravel scattered almost all over the surface of the earth do not belong to one violent and transitory period."

He apparently adopts the idea subsequently taken up by De Beaumont, viz. that deluges were caused by the sudden elevation of mountain-chains. De La Beche in 1834 takes the same view, and accurately points out the probable northern origin of the erratic blocks scattered over the north of Europe; he suggests that the elevation of the bed of the northern ocean occasioned such a deluge, and adds—"such waves (elsewhere called *waves of translation*) would necessarily tend to float the northern glaciers with their usual burdens of blocks of rock, lifting them to the southward[1]."

[1] *Researches in Theoretical Geology*, pp. 388, 389.

In this curious theory therefore we find some perception of the true explanation, but obscured and distorted by the cataclysmal ideas which had so long obtained possession of men's minds. The successive editions of Lyell's Principles of Geology contributed greatly to remove the old and deep-rooted belief in cataclysms and rushing waters, and to show how most geological phenomena may be explained by the continued action of agencies which are now actually operating in different parts of the globe.

The mistake of placing the older valley-gravels amongst the Diluvial detritus began to be noticed. Lyell pointed out that there might be Alluvia of various ages (see 4th Edition of Principles, 1835, Vol. IV. p. 209), and he appears to use the same term for denoting all superficial accumulations, to the entire exclusion of Diluvium.

The difficulty of distinguishing between the so-called Diluvial and the older Alluvial detritus is commented upon in Phillips's *Guide to Geology*, 2nd edition, 1835.

In 1837 Dr Buckland withdrew his opinion regarding the identity of the Diluvian epoch with the Noachian deluge, though he retained the term Diluvium and the idea of great inundations of water. After this recantation, however, the name was gradually dropped, and the deposits began to be spoken of as *Drift* or *Northern Drift*[1]; the theory of ice-agency was resuscitated and finally adopted; for the transporting power of icebergs had been suggested long previously, and is mentioned in Conybeare and Phillips' Geology (1822) as an attempted though improbable method of accounting for travelled boulders.

Our present knowledge of the Drift deposits has resulted from a more careful examination of their distribution and contents than had previously been undertaken;—according to Mr Trimmer[2] it was Prof. Johnston about the year 1840 who first called attention to the necessity for maps of the surface geology, which should exhibit as he says "not only the limits of the rocky formations, but also the nature and relative extent of the superficial deposits (Drifts) on which the soils so often rest and from which they are not unfrequently derived."

[1] By Dr Mitchell for instance in 1838. P. G. S. III. p. 3.
[2] *Quart. Journ. Geol. Soc.* Vol. VII. p. 37.

Mr Trimmer himself says, "That maps of the surface geology of these Islands would be of great utility, must be obvious to everyone who combines agricultural with geological knowledge, and who is aware of the extent to which our country is covered by the superficial deposits, whether we call them Drifts, Erratic Tertiaries, or by any other name." In consequence of the hint given by Prof. Johnston, Mr Trimmer was induced to enter upon the task of mapping the surface geology of Norfolk during the years 1844—1846. The results of this survey were entered on the ordnance-map, and the author contributed a paper on the Distribution of Soils to the *Journ. Roy. Agric. Soc.* Vol. VII.; while the more purely geological details were embodied in a memoir written for the Geological Survey but never published, the main generalizations were however given in two papers communicated to the Geological Society in 1851[1]. He regards the distribution of the Drifts or Erratic Tertiaries of Norfolk to be such as would have resulted from the action of shore-ice on gradually sinking land, and classifies them under two heads: (1) Boulder Clay, or *Lower Erratics;* (2) Sands and Gravels, or *Upper Erratics;* believing this arrangement to hold good over the whole of the Eastern Counties. (See Tabular View in *Q. J. G. S.* Vol. IX. p. 295. 1853.)

In 1857 (just before his decease) Mr Trimmer became aware of the existence in the Gorleston cliffs of an Upper and Lower Boulder Clay separated by a thick mass of sand. In his former papers he had thought that there was only one Boulder Clay, for having traced the Upper Clay (characterised by an abundance of Oolitic detritus) over the south of Norfolk, and believing the Cromer Till (containing blocks of Scandinavian origin) to be confined to the north of the county, he had supposed the two clays met on the same level. The sands underlying both he referred to the Crag series, but he finally accepted the results of Mr Gunn's observations as establishing the fact that the Upper Boulder Clay overlaps the Lower "with a mass of sand interposed[2]." In 1864 Mr S. V. Wood junr. read a paper before the Geological Society "On the Drift of the East of England and its Divisions." He demonstrated more fully the

[1] *Quart. Journ. Geol. Soc.* Vol. VII. p. 19 and 38. [2] *Ibid.* Vol. XIV. p. 171.

succession which was hinted at in Mr Trimmer's last paper, and indicated the distribution of the several divisions over the whole of East Anglia; he maintained that the main mass of the Boulder Clay overlaid the Sands and Gravels which cap the cliffs along the Cromer coast, and that these therefore must be distinct from the Gravels overlying the Boulder Clay in the centre of Norfolk. Mr Wood however still continued to divide the series into two groups, an *Upper Drift* and a *Lower Drift*, the latter being again divided into an Upper and Lower series[1]. The above-mentioned paper was withdrawn from the Geological Society and privately published in 1865, when he saw the desirability of a more simple terminology, and proposed the following:

1. Upper Drift (= Upper Drift, 1864).
2. Middle Drift (= Upper series of Lower Drift, 1864).
3. Lower Drift (= Lower series of Lower Drift, 1864).

Mr Wood's more recent views on the Glacial Series are published in the preface to his father's Supplement on the Crag Mollusca, which includes "An Outline of the Geology of the Upper Tertiaries of East Anglia:" he here adopts the name of *Glacial beds* in preference to that of *Drift*, and the various divisions of the series are described in some detail according to the ascending order given in the following classification.

1. Pebble beds ...
2. Cromer Till ... } ..... = Lower Glacial.
3. Contorted Drift
4. Sands and Gravels ..... = Middle Glacial.
5. Great chalky Boulder Clay .... = Upper Glacial.
6. Plateaux Gravel ..... } = Post Glacial.
7. Estuarine and Valley Gravels

In 1863 Sir Roderick Murchison, then Director General of the Geological Survey, decided, "that as the superficial drift deposits attain a thickness so considerable in many parts of England that they conceal the solid geological formations," it would be desirable to publish special maps of these districts showing the superficial deposits, and to re-survey certain areas in order

[1] *Quart. Journ. Geol. Soc.* Vol. xxi. p. 141, and *Ann. Mag. Nat. Hist.* 1864.

to insert these Drifts and Gravels. This work has been in progress ever since, and has been completed over most parts of the South-eastern counties. The only maps yet published, however, are sheets 1, 2, 7, 48, S.E. and 64 of the *Ordnance Survey* and the excellent map of London and its environs. Two descriptive Memoirs have also been published, one by Mr Whitaker, entitled "A Guide to the Geology of London," the other, on the Fenland, by Mr S. B. J. Skertchly. Memoirs on the other sheets are likewise in course of preparation.

Having thus indicated the history of opinion regarding the Post Tertiary beds, I will proceed to the consideration of such portions of these deposits as are found in the county of Cambridge, and form the subject of this essay.

CHAPTER II.

LITERATURE OF THE SUBJECT.

The occurrence of various drift deposits and superficial gravels in the county of Cambridge has been noticed by many geological writers since the beginning of this century. Some of these authors have described important local sections, others have given a general account of the distribution and relations of the several beds, and most of them have discussed at more or less length the questions connected with their origin and mode of formation. Before, however, we can hope to ascertain the complete and correct history of the deposits under consideration, it is necessary that their distribution and mode of occurrence should be much more accurately known than they hitherto have been; it is therefore the object of the present essay to add more facts to our stock of information on these points, and to present as complete an account as possible of the accumulations which are met with in the Cambridgeshire district; but before entering on such detailed descriptions, it will certainly be desirable to review what has previously been written on the subject. With this view I have prepared brief abstracts of the various papers and memoirs treating of the Cambridgeshire drifts, arranging them in the order of their publication; in doing this I have endeavoured to avoid the description of sections which would be subsequently repeated, mentioning chiefly the localities described and the conclusions arrived at by the several authors.

The earliest notice I have been able to discover which refers specially to the drifts of this county is from the pen of the

Rev. Prof. Hailstone, sixth occupant of the Woodwardian chair at Cambridge; this is entitled—"Outlines of the Geology of Cambridgeshire," read before the Geological Society in 1816, and published in the *Trans. Geol. Soc.*, Vol. III. p. 243.

Herein he observes that "upon some of the highest hills near Cambridge a deposit of gravel and loose stones in horizontal layers has been found resting immediately upon the chalk." He notices that it contains many pebbles derived from strata lying to the North and N.W., and remarks upon the difficulty of conceiving how the more tender fragments can have been transported without having been entirely destroyed, (the agency of ice did not apparently suggest itself to his mind). "The gravel," he says, "contains numerous fragments of strata belonging to the Oolitic series, which occur in the neighbouring counties of Northampton and Rutland..., but the prevailing material is the pale blue or light grey variety of flint with traces of alcyonium &c., which is chiefly to be found in Lincolnshire and Yorkshire, according to my observation."

From the great difference in character as well as in level between this gravel and that dispersed over the plain below, he rightly concludes that they belong to different epochs. The two localities he mentions for this gravel are the summit of the Gog Magogs and a hill near Harston about 5 miles S.W. of the former; the latter spot was visited by Mr Warburton, whose observations upon it are given in the paper, together with a list of the derived rocks and fossils found there.

1818. In a paper "On the Strata of the Northern Division of Cambridgeshire," *Trans. Geol. Soc.* v. p. 114, Mr Lunn treats mainly of the Lower Greensand and Gault, but he evidently confused the Boulder Clay with the latter formation, since he speaks of it as overlying the ferruginous sand at Gamlingay, and describes the villages of Hatley, Great and Little Gransden, and Caxton as situated on the *Gault;* since however these all stand on Boulder Clay, we may take his description as chiefly applying to this formation. He mentions that in the parish of Long Stow are many beautiful septariæ, together with rounded flints embedded in the clay, and that the fossil *cornu-ammonis* is also abundant.

1825. Next we come to the papers previously mentioned

as communicated by Prof. Sedgwick to the *Annals of Philosophy*, Ser. 2, Vols. IX. and X. (See p. 4.)

In the first of these he takes the fenlands of Cambridgeshire as a typical example of the alluvial deposits, and briefly describes some of their physical features, characterising them generally as exhibiting several levels of distinct fenny regions, interrupted here and there by extensive protuberances of diluvial gravel.

Under the head of diluvial formations he remarks that "the true relations of the diluvial detritus are beautifully exemplified on the flanks of the Chalk Hills which skirt the south-east side of the marsh-lands above described"....."it is constantly seen to rise out from beneath all the alluvial lands, and sometimes to lie in scattered masses on the very top of the Chalk Downs."

The Diluvium he mentions more particularly in the second communication, where, as we have already seen, he divides the deposits into two classes; among the Gog-Magog gravels he speaks of finding rolled masses of granite and porphyry pebbles resembling those in the New Red Sandstone, masses of trap and mountain-limestone, and a fine series derived from the Oolitic formations.

1836. Dr Fitton, in his well-known memoir on the Strata between the Chalk and the Oxford Oolite, makes some mention of the Cambridge Drifts at p. 303, of *Trans. Geol. Soc.* Ser. 2. Vol. IV. He says, "Another general circumstance which characterises the north-east of Cambridgeshire is the great extent and varied composition of the transported masses with which the strata are often invested. This superficial deposit includes... rounded pebbles of chalk in such abundance as to form a very large proportion of the entire mass. With these are certain fossils...Belemnites and Gryphites, portions of skeletons of Elephants, Rhinoceros, Hippopotamus, Deer, Gigantic Oxen and Horse. The mass thus composed forms many of the hills on the borders of Cambridge and Essex, and occupies a great part of the platform which runs along the confines of the former county and Huntingdonshire; a brown variety of it obscures the junction of Gault and Lower Greensand, W. of Cambridge, forming an upland which extends from Bourne by Toft and Hardwick to Dry Drayton, where it declines into the plain."

He notices that these masses of Drift closely resemble those he had already mentioned in the counties of Bucks and Bedford; but it is evident that the older river-gravels containing Mammalian remains are here still confounded with the true Diluvial or Glacial deposits.

1837. In a paper on the Geology of Suffolk by Mr W. B. Clarke, *Geol. Trans.* 2nd Ser. Vol. v. p. 365, the Diluvium is divided into three classes—(1) Clay, (2) Gravel, (3) Erratic blocks. Under the head of Diluvial Clay he says, "This deposition covers a great portion of the county, and extends into Norfolk, Cambridgeshire and Essex; a large portion of the clay is of a yellowish hue, but the greater part is blue." He describes its general distribution, and notices that its western extension is limited by a line drawn through Haverhill and Newmarket; The gravel he regards as less generally diffused than the clay, sometimes lying underneath it, but often mixed up with it; and he considers the river valleys to have been excavated through both clay and gravel.

1838. "On the Drift from the Chalk and the Strata below the Chalk in the counties of Norfolk, Suffolk, Essex, Cambridge, &c."—is the title of a paper by Dr J. Mitchell in the *Proc. Geol. Soc.* Vol. III. p. 3; but only an abstract is there given. He apparently described the Drift deposits, noticing the prevalence of Boulder Clay, which he says is sometimes overlaid by sand and gravel, and sometimes contains or rests on such deposits. In Cambridgeshire he mentions Ely and the country between Caxton and Arrington, noticing the enclosed transported rocks, and concluding that the materials came from a point East of North, derived in part from Scandinavia and in part from the destruction of strata which once occupied the site of the German Ocean.

1844. A notice of the occurrence of Land and Freshwater shells with Bones of extinct animals in the Gravel near Cambridge, by Rev. P. B. Brodie, occurs in the *Trans. Camb. Phil. Soc.* VIII. p. 138. He describes the section then exposed in the Barnwell gravel-pit as exhibiting alternating layers of fine white sand and pebbly gravel, resting upon a thin bed of brown clay, the whole thickness amounting to about 20 feet. He says, "The stratum in which most of the shells occur is composed of

a thin bed of shelly gravel abounding in many perfect specimens and comminuted fragments of the same fossils; to this succeeds an equally thin bed of fine white loam, containing shells far more perfect but less numerous." He had reason to think the sand and the loam contained a somewhat different collection of molluscs. He gives a list of 18 species.

Prof. Sedgwick adds a note to Mr Brodie's paper, commenting on the different kinds of Diluvial deposits near Cambridge; these he now groups into three divisions.

(1) The great brown clay, forming the table-land between Cambridge and Bedfordshire.

(2) The coarse gravel, occupying the crests of the Gog-Magog and Harston Hills, and containing fragments from most of the older formations in England.

(3) The fine flint-gravel of the plains, covered by the bog earth and alluvium.

He mentions bones of Mammoth and Rhinoceros as having been found in the Brown clay(!), and cites the following mammals as represented by bones from the Barnwell gravel: Mammoth (common), Equus (common), Rhinoceros (common), Bos (very abundant), Hippopotamus teeth (rare), Cervus (several sp.), Irish Elk (horns of).

1845. At the British Association in 1845 Prof. Sedgwick read a paper "On the Geology of the neighbourhood of Cambridge[1]," wherein he gives some description of the Brown Clay, noticing its contents, irregular thickness and distribution; he believes that 99 parts out of 100 of the whole mass are derived from the country of the Great Fen Clay (lying to the north). With regard to its origin he says that "Icebergs may during the period (of submergence) have transported boulders to a great distance and dropped them among the superficial deposits of the country; but no conceivable action of icebergs could have scooped out the great hollow of the Fens and spread the materials far and wide over all the higher lands on the south-east side of the Great Level." He further remarks that in the neighbourhood of Cambridge there are no old local freshwater deposits above the Brown Clay, like those found on the coast of Norfolk. The expectation implied in this remark is accounted

[1] *Rep. Brit. Assoc.* Trans. of sections, p. 44.

for by the fact that the Cambridge Boulder Clay and the Cromer Till were at this time thought to be one and the same deposit.

1847. An Essay on the "Farming of Cambridgeshire" is to be found in the *Journ. Roy. Agric. Soc.* Vol. VII. p. 35, by S. Jonas Esq. A brief outline of the Geology of the county is here given, and illustrated by two rough diagrammatic sections, one from Gamlingay to Madingley, the other from St Ives to Swaffham. He remarks that the southern and central portion of the county is light land, consisting of chalk covered in places with diluvial sands and gravels; but that the eastern part adjoining Suffolk and Essex has a heavy clay-soil which requires draining. The western side of the county is also much covered by a tough tenacious clay-soil, though the lower lands afford a good deep staple. Lastly he mentions the Isle of Ely and the Fen lands in the northern part of the county.

1861. In a supplement to a lecture "On the Strata near Cambridge and the Fens of the Bedford Level," published in 1861, Prof. Sedgwick gives a much fuller account of the Drift deposits. The evidence for a recent glacial period had then been more fully developed, and the Professor assumes the submergence of the British Isles and the transport of Drift by means of ice-floes and icebergs. For the resulting accumulations he adopts the name of *Diluvial Drift*, but still groups with them the higher and older portions of the Cam Gravels. The term *Boulder Clay* is now used instead of *Brown Clay*, by which name he had formerly designated it, and he notices that "In all places, where it is seen near Cambridge, it contains many rolled fragments of Chalk; and the abraded Chalk is sometimes so abundant as to give to the Clay a tinge of light grey," he briefly indicates the distribution of this Boulder Clay over the Eastern Counties, referring to Mr Barrett's map (published in 1859) for its disposition near Cambridge.

He next describes the coarse Gravels found on the Harston, Stapleford, and Gog-Magog Hills,—he observes that specimens of many of the great rock formations of England may be obtained from these deposits, and instances some found by himself...."None of the rock specimens," he says, "are perfectly angular. They have been partially rounded, and a few of

them are grooved and scratched, but with much irregularity. The grooved specimens do not generally look like rocks that had been grooved by the glaciers of an alpine valley; but rather like rocks which, having been mechanically acted on by the drifting ice of a glacial shore, had then been borne away on ice-rafts, and stranded on the hills where we now find them. No shells, or other organic remains, have been found in these deposits of coarse Gravel."

I have quoted the above passage in full, in consequence of the accurate observations and acute deductions it contains, which partially anticipate the conclusions arrived at in a subsequent part of this essay. Prof. Sedgwick proceeds to notice the flint-gravel covering the plains bordering on the Cam, and he still refers the formation of these gravels to the "long continued action of the waters of the sea, as it was gradually falling to its present level, near the end of the glacial period," although he observes that the stones are more angular and less waterworn than in most marine gravels. As regards the relative ages of these deposits, he knew of no evidence to show whether the Boulder Clay is older or younger than the coarse Gravel. But he mentions the fact of flint Gravel overlying the Boulder Clay near Ely, and also on the St Neots road, a few miles from Cambridge.

Lastly, the marine Gravels at March are referred to, and the indications of their dipping under the Boulder Clay are spoken of as doubtful. The large clay-pit near Ely, called Roslyn or Rosswell Hole, is referred to at p. 28 of Prof. Sedgwick's paper just mentioned, and a diagrammatic section is given of the beds therein exposed.

1864—5. This pit is the subject of subsequent papers by Mr Seeley, entitled "On a Section of the Lower Chalk at Ely," *Geol. Mag.* I. p. 150, and "On a section discovering the Cretaceous beds at Ely," *Geol. Mag.* II. p. 529. In the former Mr Seeley gives a description of the appearance which the beds presented before the year 1862, and adopts the explanation of their relative position which had previously been suggested by Prof. Sedgwick, *viz.* that Chalk and Boulder Clay had been faulted down together against the Kimmeridge Clay. In the latter he gives a sketch of the section as seen in 1865, and he

describes the Boulder Clay as extending from top to bottom of the pit, and being full of all sorts of rocks; "at one place," he says, "the upper part is devoid of pebbles or boulders, and at the north end there are rough courses of nodules making a kind of curved stratification...The Clay is capped by about 15 ft. of Gravel, in part interstratified with it."

In 1865 Mr Searles V. Wood, Junr. published a map of the Upper Tertiaries in the Counties of Norfolk, Suffolk, Essex, Middlesex, Hertford and Cambridge, with remarks and sections (privately printed). In this he establishes the divisions of the Upper, Middle and Lower Drift, describing their general position and the relation of the latter to the underlying crag. He looks upon the Cromer Till as a Marine Drift but considers its inland chalky representative to have resulted from the action of local glaciers; the Middle Drift he speaks of as a marine though littoral formation, accumulated in channels and straits between islands which he believes to have been submerged at the incidence of the Upper Drift or true Boulder Clay; this, he says, "bears evidence of being the deposit of an open sea burdened with floe-ice, drifting from shores of Cretaceous and Jurassic strata." At p. 13, he remarks upon the position of the Upper Drift near Sandy and Gamlingay and states that it is here bedded round the Lower Cretaceous sand "which rises like an island from its midst." His explanation of this is not very clear, but if I understand him rightly he believes it to have been an island in the sea of the Middle Drift, and that the Boulder Clay was dropped first round it and then on it as the area sank beneath the waters of the Upper Drift sea; and that subsequent denudation has removed nearly all the Boulder Clay from the top of the sands. The map, of which these remarks are in explanation, purports to show the distribution of the Crags and of the three divisions of the Drift in the counties mentioned; among the sections are several through parts of Bedford, Cambridge and Huntingdon, illustrating the relation of the Boulder Clay to the Middle Drift and Neocomian Sands.

1866. In a paper on the Warp and Trail[1], the Rev. O. Fisher illustrates his views by a section in an old gravelpit, Victoria Road, Cambridge; the succession here seen was as follows:—

[1] *Quart. Journ. Geol. Soc.* XXII. p. 561.

a. Warp (of Mr Trimmer) forming pockets or channels.
b. White sandy brick-earth (much contorted).
c. Yellowish sandy earth.
d. Fine sandy gravel.
e. Yellowish brick-earth.
f. Fine gravel, more contorted than the contiguous layers.
g. Sand.
The sands contain Bithinia, &c.

The irregularities observable between *a* and *b*, which Mr Fisher describes as similar to the tenons in the framework of a dissected puzzle, are considered to be the sections of channels of drainage. In the Cambridge gravel pits, he says, "the percolation and consequent erosion seem to have taken place in the layer beneath the ductile Clay, which is folded into such remarkable forms."

He remarks with truth that these contortions must in some way or other have resulted from sub-aerial causes and cannot be due to any kind of ice-action.

1866. In "A Sketch of the Gravels and Drift of Fenland[1]," Mr Seeley describes the Drifts in this part of Cambridgeshire. Following Prof. Sedgwick's triple Classification and commencing with the Boulder Clay, he notices its colour, thickness, contents and extent over the high ground immediately West and N.W. of Cambridge. He gives a section of the Fossiliferous Gravel at March, from which this marine deposit would appear to be intercalated between two sheets of Boulder Clay. "Tracing this Gravel south to Wimblingdon, near the railway station, the deposit, quite at the surface and only a foot or two thick, rests on one of the thin stonebands so common between the Oxford and Kimmeridge Clays. It is a fine sandy gravel with the usual shells; but the argillaceous limestone rock was drilled with the burrows of Pholades, the shells being still in the holes."

He proceeds to say that the gravels are somewhat continuously spread southwards by Chatteris, Somersham, Earith, St Ives and Willingham to Swavesey, and that he had found marine shells in gravel taken from old pits near Drayton Gate House. From the gravel at March he cites 20 species of Mollusca.

[1] *Quart. Journ. Geol. Soc.* Vol. xxii. p. 470.

The fine flint-gravel in the vicinity of Cambridge is next treated of, and its extent to the North and East of that town briefly noticed; Mr Seeley records the occurrence of shells at the Observatory, at Barnwell, Chesterton and Oakington, and teeth of Rhinoceros tichorhinus from a patch near Comberton. He minutely describes the character and contents of the Barnwell Gravel, giving a list of the Mammalian remains and of the Land and Freshwater shells.

Lastly he refers to the Coarse Gravel on the Gog-Magog Hills, from which he had collected boulders of the Palæozoic rocks of North England, fragments of the Yorkshire Oolites and of the Red-rock of Hunstanton; he remarks that the flints are often unbroken and that there is a rough stratification; he states also that descending on the east side towards Fulbourn "it becomes Boulder Clay," by which expression Mr Seeley probably intends to refer to a stiff sandy loam, like re-arranged Boulder Clay, now seen to overlie part of the gravel on this side. The remainder of the paper is occupied with theoretical considerations, which only appear in abstract.

These were subsequently printed in the *Geol. Mag.* Vol. III. p. 495, under the title of "Theoretical Remarks on the Gravel and Drifts of the Fenlands." These only demand a brief notice, as some of his conclusions have already been shown to be without foundation, and others are disproved by the observations recorded in future portions of this Essay.

(1) In the Boulder Clay of Ely, he states that he has found old and thick specimens of Tellina like those in the Lower Boulder Clay of Norfolk; from this and the [supposed] fact that it rests on beds which have since been removed by denudation from the country, he concludes that it is the oldest Drift in the Cambridge district, and correlates it with the Brown Clay or Till of Cromer.

(2) Coarse Gravel; he mentions three cases of such gravel overlying Boulder Clay, *viz.* in the Ely pit; on the Hogs-back going to St Neots, and on the Gog-Magogs. His observations on these coarse gravels agree in the main with my own, and his facts quite warrant him in concluding that their materials were derived from the destruction of the glacial Clay, which was at that time more widely spread. In his own words: "They

seem to be masses of re-constructed Boulder Clay, washed of its mud and converted into gravel." When however he ventures to correlate both the Hill-Gravels and the blue Boulder Clay with the contorted Drift, he is in entire opposition to the facts and conclusions, published by Mr S. V. Wood, Junr., in the previous year.

(3) Concerning the so-called "Fine Gravel of the plains," Mr Seeley imagines that the physical geography of the district demonstrates all these beds to have been of marine or estuarine origin, and comes to the extraordinary conclusion that they correspond to the Upper Boulder Clay and coarse Gravel of Norfolk. At Overton and Whittlesea he says they contain land and estuarine shells; at March, marine; at Doddington and Drayton, marine; while the Barnwell stratum he would refer to an intercalated freshwater band.

I shall have occasion to show in the sequel that several different series of gravels have here been confounded and treated together under the name of "fine gravel of the plains."

1867. A detailed paper on the Post-glacial structure of the South-East of England by Mr S. V. Wood, Junr. appeared in the *Quart. Journ. Geol. Soc.* Vol. XXIII. p. 394.

In this he argues that "the entire valley system of the East of England originated in centres of arc-like or curvilinear disturbance, which immediately preceded the elevation of the bed of the sea from which was deposited the wide-spread deposit of Boulder Clay forming the latest of the Glacial beds of the South of England."

He illustrates this opinion by sections through some of these post-glacial upheavals, one of which is across the Cam valley from Eversden on the N. to the Chalk Hills above Royston on the S. and shows the Boulder Clay overlapping the Mid Drift towards the N.W. He does not seem to see however that the disposition of the Drifts in the three sections on p. 402 is just as easily explained by the supposition of the pre-glacial existence of the chalk escarpment, as by its subsequent post-glacial upheaval. The facts collected for this essay have led me to take the former view, and I cannot but think that the whole theory of curvilinear elevations rests upon a very slight foundation of evidence.

1868. The Roslyn or Rosswell Hill Clay-pit is the subject of a communication from the Rev. O. Fisher, *Camb. Phil. Soc.* and *Geol. Mag.* Vol. v. p. 407, in which he dissents from Mr Seeley's mode of accounting for the presence of the Cretaceous beds, and considers them to form a Boulder-like mass in the Glacial Clay, similar to those in the cliffs near Cromer. He gives a ground plan of the pit and notices that at the western end, the chalk thins out and the Boulder Clay passes beneath it. He believes the hollow to be a trough ploughed out of the Kimmeridge Clay and the mass now occupying it to have been dropped by an iceberg. The slickenside surfaces "only occur in recent slips of the Boulder Clay and not along the junction between the two clays;" he therefore concludes that the evidence in the pit is against any theory of faulting, though he acutely observes that if the country were mapped and a fault affecting other strata traced through the pit this would settle the question in its favour. In the same volume of the *Geological Magazine* these views of Mr Fisher are criticised by Mr Seeley and the "Boulder hypothesis" is scornfully rejected. Mr Seeley conceives the facts to prove (1) that there is a sequence from Chalk to Kimmeridge Clay, (2) that the sands under the Gault may be connected with those outside, above the pit, (3) that indubitable slickenside occurred in the junction between the Boulder Clay and the *Cretaceous beds* figured in *Geol. Mag.* II. p. 532. He adheres to his previous statements and conclusions regarding the faulting of the strata.

1871. In a paper "On Phenomena connected with Denudation, observed in the Coprolite pits near Haslingfield[1]," Mr Fisher describes the sections then observable; in these the upper portion exhibited a variable thickness of soil containing land shells, to which he gives Mr Trimmer's name of "Warp."

Below this is found the disturbed soil which Mr Fisher has elsewhere denominated by the name of "Trail" (see *Q. J. G. S.* Vol. XXII. p. 553): this he describes as sometimes little else than disturbed clunch with occasional pebbles and boulders, but at other times containing patches of clayey gravel and sand. In accounting for the presence of this "Trail," he rejects as inapplicable the agency of rivers, admits that it may possibly

[1] *Geological Magazine*, Vol. VIII. p. 65.

be due to rainwash, but finds some difficulties in the way of this explanation. Amongst these he adduces two instances of lateral thrust, causing a reduplication of the coprolite bed, one of which he accounts for by supposing the upper bed to be a travelled mass in the trail. Finally from these and other considerations he concludes that the irregularities in the surface of the Gault near its outcrop are probably due to the action of land ice, and that the gravelly "*trail*" above is the remnant of the moraine profonde which was pushed forward beneath it.

1872. "An Outline of the Geology of the Upper Tertiaries of East Anglia," by Messrs S. V. Wood Junr. and F. W. Harmer, appeared as a preface to the volume issued as a supplement to Mr S. Wood's Monograph on the Crag Mollusca (*Pal. Soc.*). The final classification of the Glacial series proposed herein has already been given in the introductory chapter. No special mention is made of these beds in Cambridgeshire, but among the Post-glacial deposits the March Gravel receives some notice. This is said to occur in the midst of the Cambridgeshire fens and to form small islands rising out of the great level, "so that there are no means of geologically testing its position[1]."

The fauna they find to be rich in Mollusca and to resemble that of Kelsea and Hunstanton in consisting entirely of recent species, which with two exceptions are now living in British seas; *Ostrea edulis* is abundant at all three localities, and they think there can be little doubt that the beds belong to the earlier or *Cyrena fluminalis* part of the Post-glacial period.

In 1872 Rev. T. G. Bonney published some "Notes on the Ely Clay-pit[2]," and these are reprinted in the form of an appendix to his "Cambridgeshire Geology" (1875).

After referring to the previous papers on the subject, he states his adoption of Mr Fisher's view, in opposition to that of Mr Seeley, and minutely describes the disposition of the strata as seen between the years 1868 and 1872. Four sections are drawn across the pit and a ground plan is also given; by this means he shows that, if the "fault hypothesis" be assumed, no less than four faults are necessary to bring the beds into

[1] From this remark it is evident that Mr Wood does not believe in the supposed intercalation of the gravels between two Boulder Clays at March.

[2] *Geological Magazine*, Vol. IX. p. 403.

the positions they now occupy, *viz.* two simple downthrow faults and two reversed upthrow faults, both hading in different directions from each other! and yet the Kimmeridge Clay on each side the pit is undisturbed and nearly horizontal. He naturally concludes that so extraordinary an arrangement renders the fault theory in the highest degree improbable; and there remain only two possible hypotheses, *viz.* either there has been a land-slip from a Chalk cliff overhanging a valley in the Kimmeridge Clay, and the Chalk once on Roslyn Hill has since been denuded away, or, the mass is an included Boulder, and has been brought to its present position on an ice-raft. He points out that Mr Seeley's section at the south end of the pit (*G. M.* v. p. 348) is certainly wrong, that the Brown Sand which with superjacent Gault is there shown between the Kimmeridge Clay and Boulder Clay, is not in situ, but consists only of numerous blocks of Neocomian Sandstone included in the latter Clay. Mr Bonney says, "I can only explain the mode in which these blocks occur by supposing that, before and during the accumulation of the Boulder Clay there was, nearly along the line of the south side of the pit, a cliff or bank of Kimmeridge Clay, capped by Neocomian Rock, from which fragments slipped and fell."

He does not think however that any such slip will explain the position of the Gault and Chalk; he fails to see any conformity between the Gault and Neocomian Sands in any part of the pit, and considering that the Gault (with presumably the Chalk and Greensand) rests now on Boulder Clay, now on Kimmeridge Clay, and now on disturbed Neocomian Sand, he concludes that the idea of these Cretaceous beds being a huge fragment or transported mass in the Boulder Clay is more in accordance with the observed facts, and that it presents far less difficulty than either of the other theories. He only differs from Mr Fisher in thinking that the valley existed before the Boulder was dropped.

1875. In his "Cambridgeshire Geology," Mr Bonney describes the Post-pliocene deposits at p. 49 and quotes largely from Mr Seeley's papers on the subject, which have been already reviewed.

Under the head of Boulder Clay Mr Bonney refers to a fresh

section in the coprolite pits near Whitwell, and mentions most of the kinds of rock-fragments found in the Boulder Clay and Hill Gravels, especially noting the occurrence of nodules from the Cambridge Greensand. He is inclined to think the Barnwell Gravel older than that of Chesterton, and notices the extent of the former towards the Railway Station. The account of the Barnwell Gravel pit is mainly quoted from that of Mr Seeley, some information about the evidences of Palæolithic man being added.

Finally he notices the absence of the Lower and Mid-glacial series in Cambridgeshire, and correctly states the relative age of the Blue Boulder Clay, Hill Gravels and River Gravels.

1876. In December 1875 Mr W. H. Penning read some "Notes on the Physical Geology of East Anglia during the Glacial Period," which were published in the *Quart. Journ. Geol. Soc.* Vol. XXXII. p. 191. Mr Penning gives an explanation of the behaviour of the Middle Glacial beds which he had been led to adopt after personally surveying large parts of Cambridge, Suffolk and Essex. He observes, as Mr Searles Wood had done, that these Gravels and Sands are overlapped by the Upper Boulder Clay which caps the Chalk escarpment and then plunges down into the Cambridge valley. He regards this valley as of pre-glacial origin, and as having formed a land-locked inlet during the period of Middle Drift, whence gravel-bearing currents were consequently excluded.

He mentions three kinds of gravels as occurring within the brow of the escarpment: (1) Recent valley gravels, (2) Some patches of doubtful age but at high level, (3) An elongated series of gravels and loams at a height of 20 to 60 feet above the present river Cam, and in some parts distant from its present course; as these contain here and there recent land shells, he concludes that they indicate an ancient course of the Cam. His general conclusions may be stated as follows:

(1) That we have evidence of but one glacial submergence followed by a corresponding movement of elevation.

(2) That there are no Middle Glacial deposits whatever within the area of the Cam valley.

(3) That the surface of the Boulder Clay was eroded and covered by gravel on emergence.

In the supplementary notes further details are given of the Post-glacial Gravels, the higher series having been found to run down the escarpment and to overlie the Boulder Clay at several points. He is inclined to consider all of them as having resulted from the action of rivers on the newly emerged land, but the series described as indicating the ancient course of the Cam he regards as representing the latest stage of all, previous to the present system of drainage. He points out that in many cases the gravels occupy hollows along the top of ridges, the gravel deposited in the old channel having preserved the clay or chalk immediately beneath, and that many of these ridges run up into coomb-like valleys among the hills.

[1877. A Memoir on the Geology of the Fenland, by Mr S. B. J. Skertchly, was published in this year by the Geological Survey; the greater part of this book is occupied by an account of the newer Post-glacial beds, but the Gravels and the Boulder Clay are also described.

Mr Skertchly classes the Fenland Gravels under three heads: (1) Ancient Valley Gravels. (2) Marine Gravels, forming beaches. (3) "Flood-Gravels," which run down from the hills into the Beach-Gravels. In describing these deposits, however, he treats them geographically, and not according to their age or mode of formation. In Cambridgeshire he notices the Fossiliferous Gravels occurring near Peterborough, Whittlesey and March, and gives a list of the shells which they contain.

The sections described under the head of Boulder Clay are mostly in Lincolnshire, but a full account is given of the well-known pit near Ely, which will be referred to again in the sequel.]

CHAPTER III.

GENERAL PHYSICAL FEATURES OF THE COUNTY AND DESCRIPTION OF THE GLACIAL DEPOSITS.

CAMBRIDGESHIRE is divisible into four natural regions or districts, which are separated by the valleys of the principal rivers that traverse the county; each district having a different geological structure and consequently presenting different physical features.

The first of these regions is that comprised between the two tributary streams of the river Cam, called respectively the Rhee and the Bourn or Linton river, the one taking its rise in Hertfordshire and the other in Essex; such portions of these counties therefore as form part of the same valley system are included in the area hereafter described. Through the centre of this district runs the river which may be considered the main stream of the Cam[1]; it rises near Quendon in Essex, and running due North by Newport, Wenden, Littlebury, Chesterford, Hinxton, Duxford and Whittlesford, is joined by the Linton brook at Shelford, whence the united streams flow to meet the Rhee about a mile below Hauxton Bridge.

The second region lies to the N.E. of the Linton stream and to the S.E. of the Cam or *Granta* as the river used to be called below its junction with the Rhee; it includes the high ground formed by the Gog-Magog and Balsham Hills and the hilly

[1] I think this branch has stronger claims to be taken as the main stream than that which is called the Rhee, for it has more important towns on its banks, its course is rather longer, and I believe the valley in which it flows to be much older than that of the Rhee.

country near Newmarket, whence the land slopes northward and north-westward down to the broad level of the South Fens. The river Lark and the hills between Newmarket and Bury may be considered as forming the north-east boundary of this district.

The valleys of the Rhee and Granta run almost directly parallel to the strike of the Chalk escarpment, following indeed very closely the main outcrop of the Chalk Marl; so that roughly speaking we may say that Chalk forms the foundation of all the south-eastern portion of the county above described, and is only covered by drift deposits where it rises into high ground in the extreme South and East.

The third district comprises the south-western part of Cambridgeshire, with the adjacent portions of Bedfordshire and Huntingdon, between the valleys of the Rhee and Granta on the one hand and those of the Ivel and Ouse on the other; the intermediate high ground constitutes a kind of table-land, and the whole district is a country of clays, the Cretaceous and Jurassic Clays are only separated by a thin strip of Neocomian Sand, while covering all and concealing them from sight over a considerable area lies a thick sheet of stiff Boulder Clay; this latter sends out long spurs to the North and East, such as those of Haslingfield, Madingley and Drayton, from which excellent views are obtained over the broad and low lying valley of the Cam. Northward the country slopes down through Histon, Oakington, Long Stanton, Rampton and Cottenham to the fens bordering the old west branch of the Ouse which receives the waters of the Cam near Thetford, about three miles south of Ely.

The old course of the river Ouse therefore separates the above mentioned southern districts from the rest of the county on the North, and the Cambridgeshire Fenland thus forms the fourth and last of the natural regions into which the county may be divided. This great plain of the fens is interrupted only by a few low islands which rise from amidst its wide expanse, and by the somewhat bolder outlines of the old Isle of Ely, which forms an irregular patch of elevated ground from Haddenham and Sutton through Stretham and Witchford to Ely and thence in a northerly spur to Chetisham and Downham.

The formation underlying the greater portion of the fen-country is the Oxford Clay; the Isle of Ely is formed of Kimmeridge Clay capped by outliers of Lower Greensand and Boulder Clay; and the other low islands are caused by banks of the older estuarine Gravels.

Having thus given an outline of the general physical and geological features of the country, I will proceed to describe in greater detail the Post-tertiary or Pleistocene deposits, treating first of the Glacial beds exhibited in each of the above named districts, and secondly considering the Post-glacial Gravels which for the most part occupy the intermediate valleys and low grounds.

The Glacial Beds.

§ *a*. *The Southern District.* This area presents an undulating surface of Lower Chalk covered here and there by a patch of Boulder Clay or early River-Gravel. It is bounded on the south and south-west by the escarpment of the Upper Chalk, which extends from Hitchin and Baldock by the hills south of Royston to Saffron Walden and Linton, and is capped with the Drift deposits which extend thence south-westward over Essex.

The boundary of the Upper Boulder Clay may be traced along the summit of the hills by Tharfield, Newsells Bury, Chishall, Heydon, Elmdon, stretching out in a spur to Strethall and Littlebury Green, but trending south-westwards from Christhall and Rockell's Farm to Arkesden and Wenden.

There are two remarkable points about the lie of this clay: first that it everywhere rests directly on the chalk, without the intervention of sand or gravel; secondly that it not only runs up to the very crown and brow of the hills above mentioned (about 500 feet high), but it appears to have also run down the northern slope of the scarp, and outlying patches occur at lower levels beyond the limits just indicated. Near Newsells Bury, for instance, a tongue runs down into the valley; near Royston there are one or two small outliers that must be at least 150 feet lower than the top of the scarp; a larger outlier caps the high ground

between Duxford Grange and Ickleton, which is not more than 200 feet above sea-level, while the scarp two miles to the southward must be nearly 450 feet high. The spur which runs eastward by Littlebury Green descends considerably towards the valley of the Cam, and farther south the Boulder Clay runs down quite into the valley by Wenden and Newport. It is thus shown that the chalk escarpment and the Cam valley were both in existence before the deposition of the Upper Glacial Clay.

The river Cam, rising among the drift-covered slopes between Quendon and Thaxted, runs at first south-westward, but turning northward by the former village, has cut for itself a valley of some depth through the hills by Newport and Wenden; in this valley several good sections of the Glacial beds may be seen.

Gravel and Sand underlying Boulder Clay and consequently taken to be Middle Drift, may be seen in a pit just South of London Wood opposite Quendon, and that village itself is probably built upon deposits of the same age.

A section about three quarters of a mile E. of Newport showed 16 feet of gravel and sand overlaid by 18 feet of Boulder Clay, the latter rolling over the gravel towards the valley.

At Wicken Bonnett, 1½ miles W. of Newport and situated in a tributary valley, there is a large pit near the Church; this exhibits about 30 feet of coarse gravel with occasional interbedded seams of fine sand and loam. The gravel is almost entirely composed of flints, mostly unworn, some of them being large nodular lumps as perfect as those in a chalk pit, only stained brown with iron; large lumps of Hertfordshire conglomerate also appeared to be common, and the material would seem to have been almost entirely derived from the destruction of Chalk and Tertiaries. The hill above is capped with Boulder Clay which rests on chalk both eastward and westward of the village, so that the gravel is only a lenticular mass at the bottom of the clay, and exposed in the valley.

The gravels which flank the river near Newport and Wenden are probably river deposits, though being to a large extent derived from the Glacial Gravels, they greatly simulate them in appearance: there is nothing in this neighbourhood which can

be considered as unquestionable Middle Drift; in many places the Boulder Clay can be proved to rest directly upon the Chalk, though there are occasionally patches of gravel and sand at or near its base.

At Audley End Station, the railway cutting on the North side of the bridge exhibits a succession of clays and loams lying in a hollow scooped out of the chalk and all inclined to the S. at an angle of about 25°. The lowest is a grey Boulder Clay full of chalk stones, and contains a thin inter-bedded band of loam; next succeeds a yellow laminated loam, and then the section becomes obscure, but there are traces of more Boulder Clay, while at the bridge yellowish brown loam is shown on one side the cutting, and gravel on the other.

Eastward of the station, and barely a mile distant, a good section has been exposed in the railway-cutting on the Saffron Walden branch; this exhibits an outlying mass of Drift, lying within the general depression of the valley and occupying a hollow in the side of the chalk slope against which the more recent valley beds rest at a lower level. Below the bridge over this cutting the following section is shown:

1.	Boulder Clay, capping the hill.....	about 14 feet.
2.	False-bedded sands and loams with a hard calcareous band at the bottom.....	„ 10 „
3.	Boulder Clay, similar to that above.....	„ 10 „
4.	Chalk rising rapidly to the east.....	„ 6 „

The calcareous band is about six inches thick near the bridge, and the loamy sand above is also similarly hardened; this infiltration has probably resulted from the presence of the impervious Boulder Clay below, which has stopped the passage of the downward percolating water and allowed the calcareous material in solution to be deposited. Beyond the bridge the sand and loam are seen to thin out wedge-wise between the two similar Boulder Clays, they can hardly therefore be called Middle Drift, and the whole series, as also that at Audley End, probably belongs to the Upper Glacial beds of Mr Searles Wood. They appear to increase in thickness towards the valley, and at the west end of the cutting the sands pass by contorted and laminated loams into the Boulder Clay above; but

this portion of the section is now rendered obscure by the overgrowth of vegetation.

From the hills north of Saffron Walden the irregular boundary of the Upper Boulder Clay is traceable through Great Chesterford Common and Park, round by Abington Park and Hildersham Wood to Hadstock; it then runs down northward and skirts the S.W. side of the valley by Linton and Bartlow. This valley here divides into two branches, and the tributary brooks occupying these have cut back the Boulder Clay as far as Ashdon Street and Castle Camps respectively; from this point the boundary turns finally northward, and may be followed over the country a little west of Shudy Camps and Horseheath.

Throughout all this country the Boulder Clay almost always rests directly upon the Chalk, and it is only in one or two localities that any intermediate gravels have been found. One of these is near Littlebury, where the road-cutting just above the words North End on the Ordnance Map appears to show an upper and a lower clay with an intercalated patch of gravel.

No more such gravel is seen till we reach the slopes above Linton, where it appears to underlie the Boulder Clay rather more extensively, and may be seen in several pits about Hadstock. In the railway-cutting near Newnham Hall Mr W. H. Penning informs me that a lenticular patch of gravel and loam occurs in the mass of the Boulder Clay, near a knob of Chalk which rises up from beneath. (See Geological Survey Memoir on Sheet 47.) At Ashdon a small pit near the Church exhibits a few feet of rough chalky gravel, but its relation to the Boulder Clay is not seen.

§ *b. Eastern District.* Eastward of Ashdon the Boulder Clay appears to stretch uninterruptedly through Castle Camps and Shudy Camps to Helion Bumpstead and the neighbourhood of Haverhill. This high ground forms the watershed between the valley systems of the Cam on the one hand and the Stour on the other; hence the small brooks and streams which form the tributaries of these two rivers run off the Boulder Clay slopes northward, eastward and westward. The lower formations are entirely veiled by the clay, nor is anything else seen till the vicinity of Haverhill is reached; where several sections show gravelly beds underlying the clay. One of these occurs about

2½ miles S.S.E. of the Church in a pit of some size disclosing the following series:

Boulder Clay	10 feet.
Lenticular patch of brown sand	6 „
Grey and variegated loam (with flint pebbles) probably due to the reconstruction of Reading Beds	6 „

In a gravel pit half a mile S.W. of Haverhill the thin edge of the Boulder Clay is seen overlying six feet of coarse gravel with large boulders, being in fact part of a boss of gravel which here protrudes through the surrounding Boulder Clay.

North-west of Haverhill there is gravel and sand in the valley, but these are probably river deposits, as the clay is found to come close down to the stream in many places.

Following the line of railway, Boulder Clay is seen near Withersfield Station, and the long cutting near Horseheath Green exposes about forty-five feet of grey clay enclosing some large boulders of Chalk and other rocks. A well made here by the contractors showed its total thickness to be 120 feet. This clay covers all the country northward round Horseheath, Withersfield and West Wickham, but the highest hills of this district are not more than 340 to 360 feet high. The boundary of the clay is continued from the point where we left it, near Horseheath along the S.E. flank of the open valley, which here runs up into the hills and in which the Chalk is exposed for a considerable distance. Crossing this hollow however and ascending the high ground upon which Balsham Wood is situate, we again find Boulder Clay covering the surface, and extending as an irregular patch in every direction round the village of Balsham, which thus occupies a central position at a height of about 370 feet above the sea.

Walking southwards we find the high ground covered by Boulder Clay through Yole Farm, Borley Wood and Short Wood; here it would appear to be rather thin, but Barrington Hill on the West again brings in a great thickness of it, and thence it runs westward down the slope towards Hildersham, where its level must be at least 200 feet lower than that of the Balsham and Barrington Hills; before the deposition of the

Glacial Clay therefore this part of the Chalk scarp existed in nearly its present position.

At Barrington Hill a thin bed of intercalated loam appears in the road-cutting about three-parts of the way up from the Linton side. Another remarkable feature of this hill is that its summit is capped with a patch of later gravel, which forms one of a series of outliers extending along the spur of hilly ground to the N.W., toward the Gog-Magog Hills. These deposits however, inasmuch as they are superior to the Upper Glacial beds, I will leave for future consideration.

Returning now to our central position at Balsham, we find there are smaller spurs and outliers of Boulder Clay westward and northward of that place. One of these caps the hills near Gunners Hall, and a smaller patch within the brow of the long valley to the east is covered by later gravels and loams.

A long spur runs out across Balsham Ditch to the Trigonometrical Station near Congers Well, the height given here being 346 feet. Returning along the northern edge of this spur, which is bounded by a long, deep, and dry valley running northwards from the hill slopes between Balsham and West Wratting, we find the Boulder Clay traceable through the latter village and thence skirting the high ground by Weston Colville, Brinkley and Westley Waterless. At all these places it rests directly upon the Chalk without any intervention of gravels, sands or loams. From Westley Waterless it appears to trend eastward, south of Dullingham, Stetchworth, Wood Ditton and Saxon Street, and the level of its boundary seems to be at the same time declining northwards, as indeed it has been along the whole line we have been following. I have not been able to obtain much information about this part of the county, but Boulder Clay occurs again on Warren Hill east of Newmarket, and may be seen in a large pit near the road, where about 20 feet of buff-coloured chalky clay is exposed. It does not cap the top of the hill, which is 267 feet high, and where the bare chalk is covered only by about four feet of sandy soil, so that the clay would not appear to rise above 250 feet. From this point we look northward over the lower plateau between Icklingham and Brandon, where the Boulder Clay sinks under newer gravels and sands.

§ c. *Western District.* The greater portion of the third district, lying to the west of the Cam Valley, is likewise overspread with a broad and often thick covering of Boulder Clay, which has filled up the pre-existing hollows and now forms an elevated plateau or upland; there is however hardly any gravel either above or below this clay, and there are few sections that merit description. I will therefore simply point out the limits and the '*behaviour*' of the Glacial Clay.

The hills above Haslingfield, Harlton and Orwell are capped with it everywhere above a height of 200 or 220 feet, but as they nowhere rise above 250 feet, a long narrow ridge of Boulder Clay is the result, probably not more than 30 feet thick at any spot; it stretches from Haslingfield chalk-pit to Orwell maypole, and thence to Cobb's Pound and Eversden Wood, a distance of four miles, and may be seen in many of the quarries between the above places; it is shown to be a stiff grey clay, full of chalk fragments, but only containing a sprinkling of other rocks, such as Red Chalk, quartzites, and nodules from the Cambridge Greensand.

It spreads out westward and descends to a lower level, closely following the outcrop of the chalk about Wimpole and Arrington; indeed the position of this outcrop and the general features of the country have clearly been determined by the presence of the Boulder Clay, and its power of resisting denudation has no doubt been the means of preserving this outlying area of chalk marl, with the underlying coprolite bed, from the destruction to which they must otherwise have been exposed.

Its former extension is indicated by the occurrence of stones and boulders over the fields far beyond its present limit; a very large boulder stands in Lord Hardwicke's grounds at Wimpole.

From Arrington the Boulder Clay continues to cap the high ground bounding the north side of the Rhee Valley by Croydon to Tadlow and Wrestlingworth, overlapping the Chalk Marl on to the Gault; its boundary passes eastward of Sutton and Potton, to the neighbourhood of Gamlingay. There is a small outlier capping Sutton Hill, and another on the hill just S. of Potton Church. From Gamlingay Wood the boundary is continued by Waresley and Gransden to Eltisley and Croxton, the numerous little streams which flow off the neighbouring high ground having

cut back its edge into a deeply indented line, and the whole of the valley from Little Gransden by Abbotsley to St Neots having evidently been excavated through the Drift by similar fluviatile action.

The Boulder Clay continues to cap the hills bounding the north side of this valley until this opens out into the main valley by St Neots.

These drift-covered hills stretch northward into Huntingdonshire, but on the eastward slopes the action of rain and streams has cut back the Boulder Clay, causing its boundary to re-enter Cambridgeshire by Graveley, Yelling and Papworth St Everard. The most noticeable feature to be observed along the northern edge of this great spread of clay is the way in which it runs out along the projecting spurs and hills separating the valleys by which it is here indented; the bounding line may thus be traced eastward from Elsworth, retreating up the hollows and curving round the hills by Knapwell, Boxworth, Lolworth, Drayton and Madingley to the high ground above Coton, the summit of which is registered at 175 feet above the sea.

South of this it is cut back by the valley of the little brook which rises near Hardwick, but running out again on the other side along the broad spur of Barton Field, it returns finally along the southern slope of these hills and bends south-westward to Toft and Caldecote; thence it descends into the valley of the Bourn, and crossing over by Kingston runs nearly up to Eversden Wood and into the long spur which was first described.

Mr H. H. Howell, who has surveyed a great part of the area (of which the circumscribing limits have been traced in the preceding paragraphs), informs me that it is covered almost entirely by grey or greyish-brown unstratified clay, its colour and contents varying somewhat according to the locality and the particular formation which happens to underlie it, but fragments of chalk and chalk flints are found everywhere in more or less abundance; Oolitic rocks of the immediate neighbourhood are likewise present in great quantity; ice-scratched fragments of the older formations, chiefly from the New Red Sandstone, Coal-measures and Carboniferous limestone, are found, but much less frequently; pebbles and blocks of Basalt and other igneous rocks also occur occasionally.

From the frequency of the words "gravel pit" on the Ordnance Map between Great Gransden and Eltisley, it might be supposed that there was here an extensive area of Glacial gravel; this however is not the case, Boulder Clay can be seen in the immediate neighbourhood, and the pits themselves appear to have been dug in small hollows or pot-holes of denudational gravel resting on the Clay.

It may be mentioned that in the valley at Caxton End near Bourne the Neocomian Sands come up to the surface, probably forming a ridge against which the Boulder Clay thins out, for it is found filling up the valley lower down. Mr S. V. Wood, Junr. notices a similar disposition of the Boulder Clay near Gamlingay (see ante p. 17), speaking of this deposit as bedded round the Lower Cretaceous Sand, the two sections however which he gives across this district are inaccurate in several particulars. In the first place he ignores the existence of the Gault upon which the Boulder Clay rests about Wrestlingworth and Tadlow, and which crops out in the valley east of Potton; it is evident moreover from the lie of the formations that it also rests upon Gault at the Old North Road Station, and that the latter must have formed a great part (at least 60 ft.) of the mass pierced by the well and called Boulder Clay by Mr S. V. Wood. The Glacial Clay merely appears to have filled up a pre-existent valley, and there is no evidence of any great scooping out of the Gault as Mr Wood supposes; there can I think be little doubt that the water was obtained from the Neocomian Sands, for there is no evidence of any Middle Drift in the neighbourhood; the gravel near Moggerhanger also is probably of later date than the Boulder Clay. I would therefore correct the section given by Mr Wood as follows; the minor details of the geology being of course omitted on so small a scale.

Fig. 1. Diagram Section from Old North Road to the Ouse Valley.

Horizontal scale 4 miles to an inch; vertical, one inch = 300 feet.

a = Jurassic Clay. c = Gault. x = Post-glacial Gravel.
b = Neocomian Sands. l = Boulder Clay.

The large outlying mass of Boulder Clay which has just been described as forming the upland between the valleys of the Ouse and Cam must be looked upon as having once been continuous with that which rested against the chalk escarpment; the surface on which it lies forms an inclined plane, the base of the clay being 220 feet high on the south and only 125 feet at Lolworth, so that there is a fall of 100 feet in a northerly direction. It has nowhere to my knowledge been proved to be more than 100 ft. thick, and its average thickness is probably much less, except where it happens to fill up a pre-existing hollow.

Thus at Scotland Farm, north of Hardwick, the well is said to be 144 feet deep, but at least 50 of this must be Gault, for that is the depth of the wells (through Gault) in the valley at Dry Drayton.

The same is probably the case at Old North Road Station; the well here is said to be 160 feet deep, but it is very improbable that the whole of this is Boulder Clay, because in the valley at Caldecote, only two miles to the N.E., about 60 feet of Gault was pierced; it would be safer therefore to assume that there is a similar amount in the former well below the Boulder Clay, especially as at Bourn, 1 mile N.N.E., in a well recently made, only 60 feet of Boulder Clay was found above the Neocomian.

[Mr Tomlison, C.E., of Cambridge, has since informed me of a well at Hatley St George, which is said to have pierced the following beds:—

	feet
"Gault" (Boulder Clay)	120
Gravel	28
Gault (probably true Gault)	22
Sands (Lower Greensand)	30
	200

This is interesting as showing gravel beneath a great thickness of Boulder Clay, but it is probably a local phenomenon, and cannot be taken as indicating the existence of a Middle Drift, or as giving the normal thickness of Boulder Clay.

The Rev. O. Fisher informs me that water was obtained at Comberton vicarage by piercing the Boulder Clay, a supply

being found in a dark lead-coloured sand with chalk pebbles underlying about 20 feet of clay; this sandy gravel is probably a similar bed to that which forms the base of the Boulder Clay near Hadstock and other places, see p. 31, the materials being exactly the same as those in the Boulder Clay, but without the compact clayey matrix.]

§ *d. The Isle of Ely.* We have already found that as we proceeded northward the Boulder Clay descended to lower and lower levels; its edge at Lolworth and Boxworth is about 120 feet above ordnance datum, and near Ely its base is about 60 feet lower.

The low ridges or hills which stand out of the surrounding fens, and constitute what was of old the Isle of Ely, are capped by the Chalky Boulder Clay except where they rise higher than 70 or 80 feet above the sea-level, as at Haddenham and southward towards Aldreth. Possibly the Glacial Clay was originally banked round the outliers of Gault and Neocomian here, as it was round the latter at Potton and Sandy.

Ely Cathedral and most of the city is situated upon the Neocomian Sand, which is underlaid by the Kimmeridge Clay (here however of no great thickness). Boulder Clay first comes on near the Union House and stretches southward till it spreads out over the high ground between Witchford and Thetford. It caps the long ridge which extends westward from Witchford by Wentworth to Sutton; it covers Sutton Field, but Mr Skertchly informs me that the town itself stands on a patch of gravel which appears to be intercalated in the Glacial Clay and that the materials composing this gravel are the same as those found in the neighbouring Boulder Clay; so that as sometimes we have Boulder Clay without the boulders, we have here Boulder Clay without the clay.

North of Ely, Boulder Clay is found at Little London and Roslyn Hill, whence it runs down in the form of a long tongue through the clay-pit called Roslyn or Roswell Hole. Here it lies in a long hollow which has been scooped out of the Kimmeridge Clay, and contains at the particular place where the pit was first opened a large boulder of gault and chalk; this has been brought by the agency of ice from some point to the east-

ward and tumbled over the south bank of the hollow, squeezing down at the same time underneath it portions of the Neocomian Sands which then covered the surface of the Kimmeridge Clay.

Mr Bonney has sufficiently described the pit in his *Cambridgeshire Geology*, and I will only mention that the section has been further cut back since the time when his description was written, so as to expose the Kimmeridge Clay as well as the Boulder Clay on each side of the great Boulder.

[Mr Skertchly in his "Geology of the Fenland" has given a detailed description of Roslyn Hole, with a plan and illustrations; the limits of the long Boulder are here indicated and its several relations to the Neocomian Sands, the Boulder Clay and the Kimmeridge Clay, are shown. The fault theory is examined and dismissed: "I am confident," he says, "that such faults do not exist, or they would be traceable across the country by interfering with the strike of the Neocomian Sands."

After describing the positions of the beds in the several parts of the pit, he states that the great Boulder of Gault and Chalk does not extend into what he calls the lower pit, but that a narrow band of Boulder Clay reaches down to the river. "In thus working round the pit it is seen that everywhere Boulder Clay is interposed between the great Boulder and the undisturbed Kimeridge Clay; that the Boulder Clay is always found below the great boulder whenever its base can be seen; that the limits of the Boulder lie within the pits, so that it is bedded in Boulder Clay; and lastly that the Boulder Clay fills a small valley in the Kimeridge Clay." He speaks of a similar old valley filled with Boulder Clay as intersected by the highway a mile east of Witchford. Again, "Large masses of chalk are not peculiar to Roslyn Hole, for one occurs in the Boulder Clay in Witcham Fields five miles west of Ely, but is of minor importance."]

From Roslyn Hill the Boulder Clay stretches northward and westward, capping the high ground by Little Street, Chetisham and High-flyers Hall.

CHAPTER IV.

THE HILL GRAVELS[1].

THE Gravels overlying the Boulder Clay on Barrington Hill, north of the village of Linton, have already been mentioned, and their connection with those so long known as existing on the summits of the Gog-Magog Hills has been pointed out. I will now proceed to describe the position, extension and character of these deposits, which have long been known by the name of the Coarse Gravel of the Hills.

The height of Barrington Hill may be taken as about 350 feet above the sea, and 250 above the stream below. As before mentioned, it is capped with coarse flint gravel, which was exposed in a small pit by the roadside just north of the letter R; this was open in 1874, but has since been filled up; it showed about six feet of gravel, mainly consisting of large-sized flints with pebbles and blocks of other rocks. Down the slope to the N.W. Boulder Clay is found; but in a road-cutting beyond and about a mile due E. from Hildersham, sandy gravel is again seen overlying the Clay. The same road crosses another patch to the S.W., and this was formerly worked near the word *Sand-pit* on the map; these patches are at a level of about 200 feet above the sea.

Westward of these another larger patch of gravel and sand extends above Hildersham and descends as far as the old sand-pit N. of the Church, having apparently overlapped the Boulder Clay so as to rest on bare Chalk at a height of not more than 140 feet above the sea, and within 40 feet of the alluvium level.

North-west of this sand-pit, at the corner of the roads, is a

[1] These gravels are fully described in a Memoir written for the Geological Survey, now in the press.

small cutting in stiff grey Boulder Clay, enclosing a lenticular patch of sandy loam, like that on the slope by "The Rivey." A pocket of sandy gravel is also visible, the remnant of a mass which has shrunk to a mere capping on the hill above.

Westward the clay appears to pass under thick beds of gravel, which cover the country to the north of Clay-pit Plantation, and which both northward and westward overlap the Boulder Clay on to the Chalk. There is a small pit in these gravels on the hill summit above the Plantation, exposing 8 feet of compact angular flint gravel stained by iron to a dark brown colour and containing an intercalated band of brown sand; the materials appear to have been sorted by the action of water, and no large stones were visible at the time of my visit.

In the road-cutting on the hill-flank midway between this spot and Little Abington Grange, quite a different kind of gravel is exhibited, though it is clearly continuous with the other. A confused mass of chalky gravel and sand with scattered flints and chalk-stones is here seen, looking as if it had resulted from the destruction of Boulder Clay and Chalk *in situ*; it is probably hereabouts that the Gravel has cut out the Boulder Clay, and impinged on the Chalk, and westward from this point it is always chalky and often intensely so.

This particular outlier ends at Little Abington Grange, but in the Chalk hollow to the N.W. another mass of Gravel occurs, which hardly makes any feature, but clings apparently to the base of the hill; an excavation in it exposes about 10 feet of coarse gravel, consisting mainly of large flints and chalk pebbles confusedly heaped together without any appearance of bedding; fragments of quartzite, *Septaria* from the Jurassic Clays, as well as pieces of Red Chalk and Cambridge Coprolites, are not uncommon. The Gravel indeed presents a very similar appearance to that of the Middle Drift in the neighbourhood of Sudbury and Clare, a *facies* which I take to be a proof of its resulting directly from the destruction of Boulder Clay and Chalk.

The hill beyond this pit appears to be thinly capped with Boulder Clay, which is seen in the road-cutting by the 50th milestone of the London and Newmarket road, and where the upper two or three feet is rearranged into a reddish loamy soil, containing stones of various sizes.

Similar material is seen in the old railway cutting to the S.S.E., where numerous boulders, many of which are of large size, lie scattered about; this may however be formed from the loamy and gravelly base of the Boulder Clay, as seen near Babraham. The higher ground of Signal Hill is capped with gravelly soil, but no exposure is visible.

The gravel pits near Worsted Lodge are dug in another outlier forming an elongated patch and lying at much the same level as that on Signal Hill; the Gravel here is very chalky, consisting at one part entirely of chalk stones, stained yellowish and packed close together. Another small recent excavation in the pit showed the following succession:

Irregularly bedded sand and fine gravel	3 feet.
Very chalky gravel	3 „
Clean grey sand (bottom not seen)	1 foot.

Gravel has also been obtained from a small hole farther east, where it contained more flints. Passing across the chalk combe in which Fulbourn Valley Farm is situated and climbing the hill towards Fulbourn Lodge we again find gravel at a similar level, apparently occupying a hollow on the northern side of the hill summit; it may be seen in the old chalk- and gravel-pits at the western end, where 6 or 7 feet of brown sand and chalky gravel are visible passing southwards into 2 or 3 feet of mere sandy clay and chalk rubble overlying the bedded chalk.

Copley Hill again is capped by gravel, as are also the Gog-Magog Hills north of Wandlebury, but no sections were exposed at the time of my visit, although the hollows of several old pits were visible.

The gravel pits which have been noticed by so many writers on Cambridge Geology (see pp. 15, 28, 36, 37) are to be found on the north side of the Old Roman way called Worsted Street, which appears to have been made hereabouts with the gravel obtained from the above-mentioned pits and holes. These are seldom dug now, and though I visited this locality many times between 1872 and 1875, I could only confirm the observations of previous describers as far as the meagre section then exposed allowed of; this was at the east end of the pit and exhibited stiff yellowish sandy clay showing slight lamination and contain-

ing stones of various sizes and inclined at various angles; the chalk pebbles were rounded, and the others angular or sub-angular, though few showed any traces of glacial striæ; the thickness shown was about six feet, but I was told that four feet of coarse rubbly gravel lay between this and the Chalk below.

The sandy clay I take to be the Boulder Clay spoken of by Prof. Seeley (see p. 36), to which material it certainly bears some resemblance; it appears more likely however to be a lenticular bed of re-arranged Boulder Clay forming part of the gravel mass.

The rock fragments to be found in this loam are—

Chalk, which formed about 50 per cent. of the pebbles.

Flints, of which there were about 30 per cent., leaving about 20 per cent. of other fragments consisting of the following rocks:

Red Chalk, more like that of Lincolnshire than the red rock of Hunstanton.
Hard cream-coloured Chalk. ? Chalk-rock.
Crinoidal Limestone. ? of Carboniferous series.
Oolitic and shelly Limestones, from Northampton or Lincolnshire.
White micaceous Grit. ? from Coal-measures.
Brown Quartzite, possibly from the New Red series.
Septaria, from the Kimmeridge and Oxford Clays.
Coprolites from the Cambridge Greensand (not rare).
Gryphæa incurva (Lias) *and G. dilatata* (Oxford Clay).

Besides these Prof. Sedgwick mentions:—

Pieces of Basalt and part of a basaltic column.
Rolled masses of Granite and Porphyry.
Pebbles resembling those in the New Red Sandstone (probably the brown quartzites above mentioned.)

All the above rocks have evidently been derived from the Boulder Clay, which contains an exactly similar collection, even *Coprolites* having occasionally been found in it; these nodules however appear to be more frequent in the gravels, although this comparative abundance may be deceptive and may be due to the sifting and collecting of the stones into narrower compass than they originally occupied in the Boulder Clay. Under any circumstances, however, it is not easy to account for the presence

of these Cambridge Coprolites more than 200 feet above the level of their outcrop on the north and north-west.

Prof. Sedgwick in 1861 mentioned similar gravel on the "Stapleford Hills"—by this he probably meant the height called *Little Trees Hill* to the south of the main road; only about a foot of gravelly soil however is now to be seen at the top of the chalk-pit. Pipes filled with stones and gravel are shown in the Shelford clunch pits on Steeple Hill.

Again, on Missleton Hill to the N.W. of the Gog-Magogs there are hollows from which similar gravel has been obtained; flints and other stones are to be seen impacted into the upper few feet of the rock in the chalk-pit on this hill.

Besides the series of outliers just described, I am not aware of any other gravels in Cambridgeshire which occupy a similar position; they appear to form a group by themselves, capping all the hills in the vicinity which rise above the limits of a certain inclined plane. This plane slopes from a height of 330 feet on Barrington Hill to a level of about 240 on the Gog-Magogs, and where the gravels descend below this plain or fill up hollows, as near Abington, we may suppose that these existed previously, as irregularities of the surface, or that they were excavated out of the Boulder Clay during the period when the gravels were formed. The latter is probably the more correct view, and the subordination of such hollows to a given plane certainly suggests marine action.

In the neighbourhood of Newmarket, however, there are some gravels which resemble those on the Gog-Magogs in being newer than the Boulder Clay, and in resting either on it or on the Chalk; but I have not been able to work out the relations of the several patches to one another, and will therefore simply describe the sections I have seen.

First are the gravel pits half a mile S.E. of Newmarket Station, where about 18 feet of gravel and sand are shown, the lower six feet consisting of fine gravel and sand interbedded, the upper twelve feet of rougher and coarser material, flints being the chief component; the gravel appears to occupy the southern slope of the valley, and from its character and position, I am inclined to think that it most probably belongs to the series of old valley gravels, which will be presently described.

The next pit lies at a much higher level, being about a quarter of a mile N.N.E. of Ashley Church; in this 10 feet of roughly-bedded chalky gravel is seen, nearly 80 per cent. of the stones being large rounded chalk pebbles, the rest are flint, with a few pieces of quartzite, Gryphæa, &c., the whole assemblage looking as if directly derived from the Boulder Clay; this gravel appears to spread over the high ground about Ashley, and may be partially underlaid by Boulder Clay, though a hasty traverse did not lead to the discovery of any direct evidence showing this to be the case.

No doubt however exists about the position of the gravel at Lipsie Wood near Dalham, this has been worked off a platform of Boulder Clay which may be seen near the entrance to the pit, and contains fragments of chalk, flint, quartzite, Septaria and Gryphæa shells. The gravel above is composed of exactly the same materials, and its present face is about 18 feet in height; some of the layers are coarse and others fine, and there are a few patches of false bedded sand; the chalk pebbles are mostly small and the flints large, a few of them being slightly worn and rounded; the general matrix is iron-stained sand, but in one place the stones were impacted in a hard clayey material that looked like re-arranged Boulder Clay.

It is possible that these Gravels are the southernmost extensions of those which spread over the country round Icklingham, Mildenhall, Lakenheath, and Brandon, and are noted for containing flint implements. This district is now being surveyed by my colleague, Mr Skertchly; and he informs me that though previous writers have described the gravels as confined to the river valleys, they really spread far and wide over the country, only as they are of greater thickness in the valleys, they have been more worked there than on the highlands. Much of the gravel is coarse and unstratified, but beds of sand occur in some places. These deposits overlie the Boulder Clay where it occurs and occupy the highest grounds as well as the lowest; the land hereabouts however never rises above a height of 160 or 170 feet.

CHAPTER V.

VALLEY GRAVELS OF THE EARLY RIVER SYSTEM.

In the higher parts of the tributary valleys, as well as in other localities nearer Cambridge, there exist certain patches of gravel and loam, regarding the age of which there has lately been much difference of opinion among Cambridge geologists, and the relations of which could perhaps hardly have been ascertained until the country was mapped in some detail.

Although similar in composition to the gravels previously described, they occur mostly at much lower levels and are entirely separated from the glacial deposits; they appear to have a distinct relation to the valley systems in which they lie, and they behave in all respects like ancient river gravels. The correspondence of these deposits with the direction of the present valleys is not however preserved in their lower prolongations, indeed so great is the divergence that near Cambridge they strike across the Cam Valley almost at right angles to its present course; at the same time their fluviatile origin becomes more apparent, for they preserve a definite line across the country, forming a nearly continuous ridge, which may be followed with few interruptions far into the regions of the Fens. We are thus led to the inference that these old gravels indicate the course taken by the first river system of the district, and we may expect them therefore to throw much light upon the history of its denudation, and upon the relative age of some of its principal physical features.

The southernmost patches of these old valley gravels are to be found in a curious hollow among the Chalk Hills near Royston, called Wardington Bottom. The beds of the lower Chalk are here affected by a remarkable disturbance which has

caused considerable deviation from their normal dip, and which may have led to the formation of the Wardington Bottom by determining the outflow of the springs[1]. The combe is certainly of very ancient date, so old indeed, as we shall presently see, that all the rest of the valley into which it originally led has been swept away by post-glacial denudation.

At the head of this valley, about one mile and a half east of Barley Church, is a small gravelly patch, but no exposure is now to be seen in it. Lower down there is a larger patch which sends a prolongation up the hollow towards Burloes Hill, and about half a mile S.W. of Known's Folly there is a gravel pit exposing—

Chalky sand (2 feet) resting unevenly upon
Fine chalky gravel, with some large subangular flints and pebbles of quartzite, sandstone, limestone, schist, &c. ...9 feet.

Large bones are said to have been found in this gravel by the workmen.

Below Known's Folly the modern little stream deserts the course of the more ancient channel, and has excavated for itself a shallow valley in which it runs north-westward towards Foulmire, while the older gravels are continued along a more easterly line, outliers of them being found on the slope of the hills by North Hall, Sharpens, Heydon Grange and onwards to Whittlesford.

About North Hall some thickness of chalky gravel and sand is found, the stones being mostly pebbles of chalk and flint, but there are many boulders of quartzite, grit and basalt. Near the farm called Sharpens a small pit exposes 10 feet of very chalky gravel, evidently occupying the old channel in the chalk, but now forming a ridge into which the beds dip on each side; sandy and loamy layers are interbedded with the gravel, and the proportion of chalk stones is in places more than 50 per cent.[2] North-eastward by Heydon Grange the

[1] Details regarding this disturbance and depression are given in the *Geological Survey Memoir*, on sheet 47, now in the press.

[2] For the notes on these and other Gravel pits I am indebted to Mr W. H. Penning, of H. M. Geological Survey, and I have since had the advantage of visiting some of them under his guidance.

direction of the old river course may be traced by the gravelly surface of the ground.

Further still another large mass of gravel is met with, covering the country north of Chrishall Grange; about a mile N. of this place it has been excavated for road material, and when seen in 1875 the pit disclosed 8 feet of rough chalky gravel underlaid by 3 feet of fine chalky sand, with a lenticular bed of fine gravel composed entirely of small chalk pebbles. The gravel was roughly stratified, and one layer was stained black by manganese or iron; a few large boulders occurred, and many subangular flints, some of them standing on end; there were also two or three small patches of contorted loam enclosing shells (Succinea and Pupa?), these appeared to have been contemporaneously interbedded, and if so, they would indicate clearly the fluviatile origin of the gravel.

This pit is situate on a flat or gentle slope, but the base of the gravel appears to be uneven, and to rise towards the North, for it runs out into the high ground, which extends as a gravel-covered ridge northward towards Thriplow, but bends eastward before reaching that village, and points towards the mass of loam and gravel to be next described.

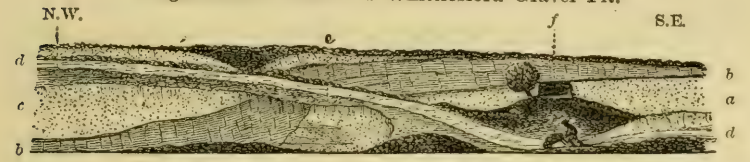
This is first seen in a gravel-pit near the main road about a mile west of Whittlesford station, but the best section is to be found in a large pit close to the station on the south side of the road. Along the eastern face of this a sandy buff-coloured loam is seen which is underlaid at the southern end by fine chalky gravel, containing on a rough calculation about 50 per cent. of chalk pebbles, the rest being chiefly flints; a small cave here excavated in the gravel is roofed by the overlying loam.

Turning back and descending into the lower part of the pit, we find it worked in roughly bedded gravel, chiefly composed of small stones, but with occasional layers of coarser material, made up of flints and large chalk stones, with quartzites, shelly oolites and fragments of Gryphæa; several pieces of laminated loam with shelly partings were also found. Farther on the gravel becomes strongly false-bedded, with intercalated patches of fine sharp sand, and the whole is cut into by a descending scoop of the overlying loam, which is strong and clayey near the base, but yellow and sandy above.

Beyond this the section is much obscured by talus, but the second bed of gravel (*c*) appeared to descend from above and cut into the loam in a similar way; and this view of the facts is shown in the annexed representation of the eastern side of the pit.

Fig. 2.

Diagrammatic Sketch of Whittlesford Gravel Pit.



a=lower gravel. *d*=roadway.
b=loam. *e*=supposed fault.
c=upper gravel. *f*=the cave.

There is no evidence of a fault at *e*, as some have supposed; the loam simply fills a hollow eroded out of the gravels by current action and passes above them undisturbed. On the west side of the pit nothing but loam is exposed; but in the next field another excavation shows gravel again with interbedded contorted loams and sands, the collocation here giving colour to the interpretation above given of the section in the larger pit. Nowhere could any shells or contemporaneous fossils be found.

The hill to the North appears to be chiefly composed of loam, and in a small brickyard just N.W. of the cross-roads the following section is shown:

	feet
Top soil	1
Laminated yellowish loam	2
Yellowish clayey loam	4
Hard buff-coloured loam	8
Softer bluish-grey loam	2+

The lowest loam here seen is somewhat the colour of blue Boulder Clay, but its intimate structure or *texture* is entirely different, and it passes up into a stiff buff loam breaking with a kind of hackly fracture. The bluish tinge of the deeper portion was no doubt the original colour of the whole mass, the upper part having weathered to its present colour. These loams are doubtless to a great extent sifted and re-arranged

Boulder Clay, mixed with a considerable proportion of sand, and an occasional chalk-pebble occurs here and there in the mass.

This ancient series of river deposits has now been traced to a point where it is cut off by the present valley of the Cam, and before proceeding to consider the direction in which it was continued it will be desirable to notice some similar deposits on the flank of this valley.

The section in the railway cutting near Chesterford station has long been known as exhibiting 7 or 8 feet of contorted yellow and brown loam overlaid by a few feet of coarse rubbly gravel. By some geologists it has been thought that the loam belonged to the Mid-Glacial series, and that it was overlapped by a high terrace of valley gravel.

There is no doubt that recent valley gravel intervenes between the loam and the river, but I am inclined to think that this is much more recent and altogether at a lower level than the gravel overlying the loam. With regard to the age of the latter, its entire separation from other glacial deposits, and its disposition along the slope of the valley, are sufficient to create grave doubts as to the propriety of grouping it with Middle Drift; while from the great similarity of both loam and gravel to the deposits above described near Whittlesford, I am strongly inclined to consider them as belonging to a similar series and as having originated in a similar manner; (indeed, a little north of Ickleton inclined beds of yellow and grey loam occur, which may have formed part of their continuation towards Whittlesford.)

Southward the loam can be traced along the railway for more than half a mile, and patches which have evidently once been connected with it trend southward along the slope above the line. It is not improbable that some of the loams and gravels about Wenden and Newport may be of the same age, but they are so mixed up with beds of later date as to make any attempt to separate them a very difficult task.

I think, however, that there is sufficient evidence to prove that a series of deposits once existed along this valley, similar in age and origin to those which have been traced from Wardington Bottom to Whittlesford; but in consequence of this valley having ever since continued to be a main line of

drainage, they have been exposed to greater denudation and fewer portions have escaped destruction; in the other case the stream has been diverted into another channel, and the older beds have been left in a much less patchy and discontinuous state.

In the Linton valley, S.W. of Bartlow, there is a patch of gravel which has also been referred to the Middle Drift, but which may not improbably belong to a branch of the present series. It is well seen in a large pit near the station, which exposes some forty feet of fine chalky gravel, iron-stained, and piped at the top, with many thin bands of sand and loam in the central part, and very chalky gravels below, all the beds dipping S.S.W. at an angle of 15°.

Two smaller neighbouring pits present the same features, and the whole mass appears to be banked up against the chalk slope; Boulder Clay caps the hill above and comes very near to the edge of the gravel, but does not appear to overlap it. Patches of gravel occur at about the same level further down the stream on either side of Linton; that which is seen about Pampisford Station and Abington Park may be of the same age, though it is difficult to separate it from lower and more recent gravels. But in the cutting half a mile N.W. of the Station gravel is again seen lying in a hollow of the chalk, and thus appears to be continued into an elongated patch capping the high ground by Pampisford Hall. The end of this outlier points directly for the Whittlesford mass, and may once have been continuous with it before the excavation of the present valley; it seems probable therefore that somewhere in this neighbourhood the three streams whose gravels we have traced down their several valleys were united into one river.

But what course did the confluent waters subsequently take? This is a question by no means easy to answer; there are beds of gravel at various altitudes lower down the valley, but even the highest of these appear to belong to a series which is the production of later times. Moreover the probable connection of the Whittlesford and Pampisford patches seems to indicate that the old river flowed either in an easterly or a westerly direction. Now it is to be noticed that the Whittlesford ridge is prolonged for some distance to the N.W., and

although it appears to be almost denuded of the deposit to which it doubtless owes its existence as a feature, a small patch of gravel still remains near Stanmoor Hall. Still further to the north-east between Newton and Harston is Red-land Hill, capped by the patch of gravel described by Warburton in Prof. Hailstone's paper on the Geology of Cambridgeshire (see p. 11). As no exposure is now to be seen on the hill, I will quote Mr Warburton's description,—he remarks "that three-fourths of the rubbly mass" is composed of rounded pebbles of very hard chalk; that the gravel also contains "numerous angular masses of striped flint, fragments of septaria, shelly limestones, and angular pebbles of trap or greenstone," likewise some ochreous balls which he looks upon as decomposed pyrites nodules, together with derived Belemnites and Gryphæa shells.

He notices the peculiar position occupied by this outlying stratum, which looks, he says, "like the partial destruction of an alluvial level by some subsequent cause." This small patch may possibly be a remnant of the series we have been following, or at any rate of some contemporaneous affluent, but beyond this point all traces are lost, having probably been carried away by the excessive denudation which this part of the valley has undergone. Leaving therefore the question of the northward continuation of this series in some doubt, we will now pass to another system of drainage in which the deposits have been much better preserved.

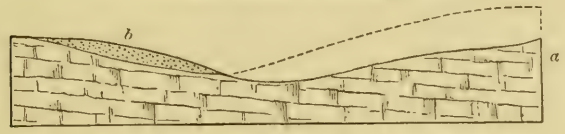
Crossing the watershed of the hills above Hildersham with their patches of clay and gravel, several deep and generally dry valleys will be found proceeding from these and the Balsham hills, and running in a northerly or north-westerly direction.

In one of these at some gravel pits marked on the map a little east of Gunners Hall, a curious section is exposed, viz. a succession of finely-bedded loams, sands and gravels, mostly of a yellow colour, and many of them false-bedded; they are all bent over into an anticlinal from N.W. to S.E., dipping very sharply on each side; this is best seen at the S.E. end, the north part appears to be chiefly composed of yellow loam. The patch does not seem to be of large extent, but is elongated in the direction of the valley.

Nothing is seen northward till the pits near Dungate are

reached; these show 6 or 8 feet of chalky and somewhat clayey gravel, containing patches of light sand, and covered in places by a reddish-brown sand; the whole is apparently made up of waste from Boulder Clay, it contains many rounded pebbles of chalk, many flints (mostly angular), pieces of limestone, sandstone, quartzite, red chalk and derived fossils. This patch lies on the slope of the hill, and similar sand and gravel may be traced northward along the ridge and also down the slope into Wratting Valley; half the hollow of the ancient watercourse is therefore preserved, while the opposite slope has been worn back, but once stood, no doubt, over the ground of the present valley, as shown by the dotted line in Fig. 3. The same feature

Fig. 3. Section across Wratting Valley.



a = chalk. *b* = gravel.

was remarked near Duxford Grange in the "Wardington Bottom" series, in both cases the gravels lying half on the hill and half in the valley. In both cases also the present valley or "bottom" only coincides with the line of the ancient watercourse in its upper and deeper portions, while lower down the old gravels gradually get up on the slopes of the valley, and eventually deserting it altogether they form long ridges raised above the level of the country beyond; such behaviour indicates at once their great antiquity, and the enormous amount of denudation which has taken place since the period of their formation.

In the present case this feature is very marked, the next outlier of gravel occurring along the high ridge which is cut through by the junction of the old and new railways to Newmarket.

A chalk pit near its southern extremity shows about 8 feet of hard chalky sand containing scattered flints, but few chalk pebbles of any size; the sandy matrix is an intimate mixture of chalk grains and flint sand, but the former has been dissolved from the uppermost foot or two, leaving the flints embedded in

a brown sandy soil; the base is piped, and pockets of light-coloured sand full of flints descend into the chalk below.

A small excavation north-west of this exhibited 10 feet of coarse flint gravel, a few lenticular patches of similar chalky sand producing a rough appearance of bedding; the whole deposit has the appearance of being quickly accumulated from the rapid denudation of Gravel, Boulder Clay, and Chalk, for the flints though sometimes cracked, are angular and unworn, and certainly have not been transported from any great distance.

About six feet of the same gravelly material is seen in the railway cuttings. And beyond this the ridge is prolonged till it is cut off by the hollow in which Great Wilbraham lies, across which it has clearly once extended to join the long gravel-capped ridge presently described.

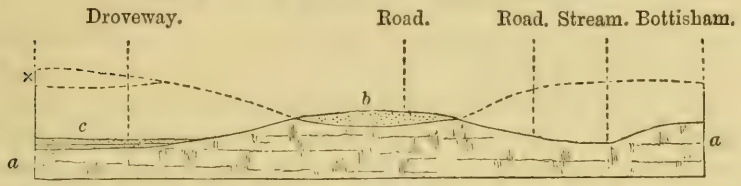
An examination of the other valleys which furrow the northward slopes of the Balsham and Wratting hills discloses in them also the existence of similar deposits, and small patches near Larks Hall have yielded Mammalian bones in some abundance; specimens are now in the Woodwardian Museum, and among them can be recognised teeth and bones of *Elephas, Rhinoceros, Hippopotamus*, and *Cervus*.

It is worthy of note also that the bottom of the neighbouring valley is occupied in places with a recent wash of sand and flints, very similar in character to the old gravels on the slope above; it has no doubt been largely derived from these, and while serving to indicate their once greater extension up the valley, it shows at the same time that even this second transportation has failed to reduce the flints to a rounded shape; long attrition is required to effect this, and the rapidity of the process here has not allowed sufficient time, for the valley is usually dry, and the detritus is only brought down by heavy rains and floods such as I was a witness of in 1875.

The patches above mentioned lead on to an elongated outlier which is cut through by the Newmarket railway near Six-Mile Bottom Station. Here material is seen precisely similar to that in the former cutting S. of Wilbraham; and beyond this point a long ridge may be followed in a north-westerly direction, till it turns westward below Quy-cum-Stow. This ridge is indeed the line of the old river-course, and it owes its existence as a

ridge to the river-gravels which rest upon it, and have protected the underlying chalk from denudation; the bottom therefore of the ancient valley is here preserved, while the hills and slopes which once formed its sides have been long since destroyed and washed away. The dotted lines in Fig. 4 (kindly lent by H.M. Geol. Survey) will give an idea of the probable configuration of the country at the time when these beds were deposited.

Fig. 4. Section across the Wilbraham Gravels.



Horizontal scale, 2 in. to a mile. Vertical scale, 200 feet to an inch.
a = chalk. *b* = ancient river gravel. *c* = gravels of Wilbraham Fen.

Some small excavations north-west of Great Wilbraham Hall exposed about 9 feet of rough flint gravel and sand; from the bottom of one of the pits I obtained the tooth of a deer, and was told that bones were frequently found. The stones here had lost some of their angularity, and the further the distance from the hills, the more rolled and rounded do the pebbles become, affording, were it needed, another proof of the fluviatile origin of the beds. The sand-pit by the wood opposite the Hall is at a lower level, and is probably near the spot where the Wratting Valley stream joined that we have been tracing, the channel of the former being intersected by the watercourse running westward from the present springs.

Close by Little Wilbraham Church there is an extensive pit, the recent diggings in which show loamy sand and sandy gravel, the former containing in one place small specimens of *Succinea* and *Pisidium*. Gravel has also been obtained from numerous holes dug in the fields north of Little Wilbraham, and a bed of loamy marl overlying gravel in one of these yielded several specimens of *Succinea*, *Helix* and *Pupa*; bones also are said to have been found. The ridge here is about half a mile wide, but it becomes somewhat narrower to the N.W., where the above section (Fig. 4) is taken, to show its relations to the present surface of the ground, and especially to Wilbraham Fen.

Between Bottisham and Quy it bends to the S.W., and extends about a mile in that direction, terminating a little beyond Quy Church, where the height of the surface is given as 60 feet above sea-level. At Quy-Water Bridge it is cut through by a more recent line of drainage; but gravelly soil is again found on the hill to the S.W., and another elongated outlier of gravel and sand extends along the Newmarket road from Greenhouse Farm to within half a mile of the railway bridge.

The direction of this patch and consequently of the old valley which it represents, strikes directly west across the present valley of the Cam, so that we might expect to find its continuation about Castle hill, and the Observatory. This is indeed the case, a small patch of gravelly soil being observable when the coprolites were worked opposite the Alms-houses at Mount Pleasant, while just beyond the Observatory there are large pits by Gravel Hill Farm, which have been worked for many years, and where the gravel is said to be 20 feet deep.

A recent excavation here discloses about twelve feet of gravel, the lower six feet being fine and irregularly bedded, containing nearly 50 per cent. of chalk pebbles, the rest being flints with a few pieces of hornstone, quartzite, &c. The upper six feet are disturbed and piped, the pockets being filled with brown sand and occasional flints, and their bottoms lined in places with films of carbonate of lime, from which we may conclude that the contortions have arisen from the solution of the chalky portion of the mass, the carbonated water having probably been guided by roots of trees in the first instance.

I did not succeed in finding any shells, though Mr Seeley states that he found fresh-water shells under the Observatory.

It is remarkable that the base of the gravel here is somewhat higher than it is further back, for its surface being 85 feet above sea-level, its base would be 65 feet, while near Quy Church it is not quite 60 feet; this would apparently indicate that there has been a slightly unequal upheaval of the area at some subsequent time; other facts bearing in the same direction will be noticed in the sequel.

In 1873 I was fortunate enough to see the northern bank of the old watercourse exposed in the coprolite diggings then opened behind the Observatory; the section ran from N.E. to

S.W., and showed a hollow filled with gravel, shelving up to the North but gradually deepening towards the Observatory grounds, and about 8 ft. deep at S.W. end.

I think it may have been hereabouts that the series of deposits first described in the higher parts of the Cam Valley was united to that coming from the east; the former must have descended the valley, and since the gravel-covered ridge now makes a sharp turn to the N.W., this may have been consequent upon the junction above suggested.

Several old gravel pits occur along the high ground between the Observatory and Girton College; at the latter place a well was sunk 10 feet into gravel without touching the gault below.

Most of Girton stands on gravel or sand, and where exposed the pebbles are seen to be small and much rolled. From Girton the ridge bends slightly to the north-east, and then turns again to the north-west; below Histon Church however it is cut through by a little brook which flows off the lower gravel plain to the eastward, and has made a valley for itself through this still older series of deposits. Another breach is made by two small streams coming in from the south-west near Oakington, and re-deposited gravel occurs in both valleys, so that there is much confusion in the gravels here.

Above Oakington however the high ridge commences again, and continues steadily towards the north-west between Long Stanton and the Huntingdon railway; in the cutting on this line, about midway between the Long Stanton and Swavesey Stations, gravel is seen overlying Oxford Clay, and thence a gravelly soil extends on the north side of the line as far as Over, where gravel has been obtained from pits along the slope facing the river Ouse. This river, like the Cam, has cut directly through the ancient line of drainage, which appears to have taken a bend to the north hereabouts, washing past the clay slopes which jut out above Bluntisham and Colne. Gravel occurs at and west of these places, but its precise relations are rather difficult to ascertain; it is furrowed by transverse valleys and appears to be flanked by more recent Fen-gravels.

At Somersham its disposition is more readily comprehended: it underlies the whole of the town, and caps the high ground to the north and north-west. A good section of it was visible

(1876) in a field near the Rectory, the pits exposing 12 or 14 feet of finely bedded sand and gravel, the latter composed chiefly of small rounded flint- and chalk-pebbles, with a few rolled pieces of yellow quartz and brown quartzite, and many broken fragments of *Gryphæa dilatata*. The total depth was said to be about 20 feet; the sands had a somewhat crag-like appearance, but appeared to be quite unfossiliferous. Northward its edge or base is very little above the level of the Fen.

About Chatteris again its position is clearly defined, as it here forms a low island or bank rising up from amidst the surrounding fens, and the town is entirely situated on this bank, which is here about three-quarters of a mile wide. Small excavations in the Nursery gardens near the Station showed 4 or 5 feet of gravel similar to that at Somersham banked up against a clayey loam; I was informed that the whole deposit was from 5 to 7 feet deep and rested irregularly upon stiff clay with occasional "large oysters" in it, but could not ascertain whether this was Boulder Clay or Oxford Clay.

The clayey loam occurs in patches among the gravel, and is left in working out the latter; they evidently bear much the same relations to one another as the loam and gravel at Whittlesford.

The gravel extends southward beyond the Mill Field and northward beyond the Gas Works, near which place it is also worked. I could discover no shells, but Mr Skertchly informs me that *Cyrena fluminalis* has been found here together with *Cardium edule* and *Tellina solidula* (*balthica*).

Near Doddington the railway cuts through gravel, but the pit near the Station at Wimblington is now grown over and no longer worked; many shells (chiefly marine) used to be obtained from this pit, which is probably that mentioned by Mr Seeley as disclosing a floor of Oolitic rock pierced by *Pholades*.

The gravel pit in the immediate vicinity of March Station is likewise grown over, but gravel full of marine shells is seen in the ditches leading into it.

[The beds were well exposed in 1872, when part of the section described by Prof. Seeley in 1866 still remained (see ante, p. 18); the succession being as follows.

Brownish clay, about 3 feet.

Shelly gravel, with false-bedding, 2 feet shown.

Talus and water, apparently hiding the base of the gravel and its junction with blue Boulder Clay below[1].

The uppermost clay was certainly not Boulder Clay, but true Glacial Clay was seen below the gravel in other parts of the pit.

A good section was observed by Mr Skertchly in Hutchison's brickyard, and noted as follows[2].

Gravel, with marine shells, now almost removed, formerly from 6 to 20 feet thick.

Boulder Clay, dark blue in colour, with many rounded and striated chalk-pebbles.

Kimmeridge Clay, dark blue, with Ostrea deltoidea in the upper part, dug to 40 feet.]

Mr Skertchly has not seen anything like true Boulder Clay overlying the gravel either in this or in any other pits, and agrees with me in thinking the whole series to be of Post-glacial age, and the general relations of the gravel to be as shown in Fig. 5.

Fig. 5. Diagram Section across the March Gravels.

a = Kimmeridge Clay. *b* = Boulder Clay. *c* = gravel.
d = loam. *f* = fen series.

About half a mile north of the Station are more recent excavations, showing fine gravels and sands full of marine shells; they are overlaid near the railway by a bed of yellowish loamy clay, somewhat similar to that mistaken for Glacial Clay by Prof. Seeley and possibly once continuous with that deposit.

I collected in these pits the following shells:

Ostrea edulis.	Buccinum undatum.	Bela turricula.
Cardium edule.	Purpura lapillus.	Littorina littorea.
Tellina solidula.	Turritella communis.	Natica Alderi ?

[1] Having lost my notes of this section, I am indebted for the above details to Prof. Bonney, with whom I visited the locality.

[2] *See* Geology of the Fenland, p. 192.

Westward of this section is a brickyard disclosing a surface of clay from which 5 or 6 feet of gravel have been removed. The top 2 or 3 feet of this clay are yellowish in colour and contain a few stones and pebbles, so that it may be the base of the Boulder Clay, the old river having here nearly, but not quite, cut down to the Kimmeridge Clay below the plain of Boulder Clay.

[This section is the same as that numbered 96 in the Appendix to Skertchly's Geology of the Fenland.]

Below is a full list of the fauna hitherto collected, 40 species in all.

Buccinum undatum.
Purpura lapillus.
Trophon scalariformis.
„ Bamfius.
Bela turricula.
„ pyramidalis.
Mangelia rufa.
Aporrhais pes pelicani.
Turritella communis.
Scalaria communis.
Littorina littorea.
* „ rudis.
Lacuna vincta.
* „ crassior.
*Hydrobia ulva.
Natica Alderi.
„ helicoides.
* „ catena.
Trochus cinerarius.
† „ helicinus.
Cyrena fluminalis.
Ostrea edulis.
Mytilus edulis.
Tellina solidula.
† „ lata.
Scrobicularia plana.
Cardium edule.
Astarte borealis.
„ sulcata.
*Modiola modiolus.
*Artemis exoleta.
Cyprina islandica.
Mactra ovalis.
„ solida.
Corbula striata.
* „ gibba.
Mya arenaria.
„ truncata.
Pholas crispata.
Rhynchonella psittacea.

* On the authority of Mr Harmer.
† On the authority of Mr S. Wood.

CHAPTER VI.

VALLEY GRAVELS OF THE PRESENT RIVER SYSTEM.

The gravels which occur in the present valley of the Cam, and along the banks of its tributaries, offer rather a complicated subject for study, inasmuch as they have been deposited at different times and at different levels, according to the changes in the courses of the streams and the depths to which they had successively excavated their channels.

Indeed it would not be possible to unravel the relations of all the ridges, terraces and patches of gravel which occur at various heights above the present streams, without carrying out a far more detailed survey of the whole valley than has yet been made, and accurately determining the height of every such terrace and patch above ordnance datum. The following pages, therefore, must be regarded as containing only a first attempt at giving a connected historical account of the river-gravels of this valley.

By Prof. Sedgwick these deposits were all classed together under the name of the Fine Gravel of the Plains, and all such beds were at that time considered to be of marine origin. Prof. Seeley perpetuated this idea, and was even bold enough to correlate them with the Upper Boulder Clay of Norfolk (see ante, p. 20), but their fluviatile origin has since been acknowledged by Prof. Bonney and other observers.

Before proceeding to describe the several terraces of gravel, I will offer a few remarks upon their general mode of occurrence, and upon the extent to which they are likely to be preserved in different parts of a valley such as that of the Cam.

The river system is composed of several streams, flowing off comparatively high ground, and uniting to form a river which opens on to a low flat country; hence, as the power of a stream to deepen its channel depends more on its velocity than its volume, it is obvious that erosion will proceed much more rapidly in the higher portions of the valley, and that the oldest gravels in these localities will be left at a much higher level above the river than those of the same age lower down the valley. Moreover, if the river lose so much of its velocity before reaching the sea as to deposit material instead of deepening its channel, the positions and ages of the gravels will be reversed, the lowest beds in the delta and the highest beds on the steeper slopes being respectively the oldest, while between the two there will be a space where the valley opens out, and where there is little difference of level between the oldest and newest deposits.

It might therefore be expected that the terraces of gravel would be found more widely separated, and more distinctly marked, as the sources of the river were approached; this is indeed the case as far as they are preserved, but it must be remembered that the atmospheric agencies of denudation take much greater effect on the steeper slopes, so that the oldest terraces in the higher parts of the tributary valleys will often have been entirely destroyed and washed down into the more recent gravels.

Consequently it is in the lower parts of these valleys and in the higher portion of the resultant main valley, where the erosive power of the stream is still considerable, but the lateral denudation is not so great, that we should expect to find these terraces best preserved and at the same time tolerably distinct from one another.

This is the case in the valley of the Cam; and for some distance south of Cambridge three sets of gravels can be clearly distinguished, but north of the town they spread out over a wide area, and there is not so much difference in level between the highest and lowest of the terraces, so that it becomes more difficult to separate them one from another.

Leaving these lower plains for the present, I will first describe the river gravels above Cambridge, taking the several

terraces separately, and endeavouring to trace them as far as possible up the tributary valleys southward, westward and eastward.

§ *a*. The highest and oldest terrace to be found in the present valley of the Cam or Granta, near Cambridge, occurs along the low ridge which runs southward from Barnwell at a level of about 45 to 50 feet above the sea. At the northern end of this are the well-known gravel pits of Barnwell Abbey; these are now nearly exhausted, and no deep sections are exposed, so that I am obliged to quote the following facts from Mr Seeley's account of the pit[1], which agree with my own recollections between the years 1871 and 1874. "Examined generally, the gravel is formed of layers which extend pretty continuously round the pit. The lowest bed exhibited is quite a coarse bed with the pebbles mostly rounded. About 2 feet above this is a bed of yellowish brown marl, almost clay, irregular in thickness from a few inches to four feet. At times, cuttings display one or two similar but thinner beds in the upper part of the section." As the pit was cut back, these thin bands appear to have thickened into a bed of greyish white marl, which is still visible on the west side of the pit and is underlaid by false-bedded sands containing shells.

"The most important stratum is the marl-bed (*i.e.* the lower marl), first described by the Rev. P. B. Brodie, see *Camb. Phil. Trans.* VIII. p. 138 (ante p. 13); in this are found fragments of plants, seed-vessels of Chara, and many shells, some fresh-water, others land forms, nearly all now living in Britain....Here too are found the bones of various mammals, nearly all extinct; and in the same bed is evidence of man in his work."

This evidence consists of an incised bone described by Mr Seeley as being apparently part of a rib of an Elephant, the incisions on which he considers to have been the handiwork of Palæolithic man[2]. No flint implements have ever occurred here, though one or two flakes are said to have been found[3].

[1] *Quart. Journ. Geol. Soc.*, Vol. XXII. p. 476.

[2] See *Brit. Ass. Rep.*, 1862, *Trans. Sec.*, p. 94.

[3] A fine specimen of the "hache" type has however recently been obtained (1878) by Mr A. J. Griffith from the pit on the other side of the Newmarket road.

A full list of the Mollusca yielded by the marl and sand is given below (58 species in all). I am indebted to Mr A. Bell for the names of many species not hitherto recorded from Barnwell.

Freshwater species.

Cyrena fluminalis (common).
Unio littoralis (common).
„ limosus.
„ pictorum.
Cyclas cornea.
„ calyculata.
Pisidium amnicum (common).
„ fontinale.
„ pulchellum.
„ nitidum.
„ Henslowianum.
Limnæa palustris.
„ peregra.
„ auricularia.
„ truncatula.
Planorbis marginatus.
„ carinatus.
„ spirorbis.
„ vortex.
„ nitidus.
„ glaber.
„ contortus.
„ corneus?
Bithinia tentaculata (common).
Valvata piscinalis.
„ cristata.
Ancylus fluviatilis.
„ oblongus.
Hydrobia marginata (rare).

Land species.

Helix hortensis (nemoralis).
„ arbustorum (common).
„ cantiana? (or fruticum).
„ ericetorum.
„ hispida.
„ concinna.
„ rufescens.
„ rotundata.
„ pygmæa.
„ pulchella.
Helicella cellaria.
„ radiatula.
„ nitida.
„ nitidula.
„ fulva.
Bulimus montanus.
„ Lackamensis.
„ (Zua) lubrica.
„ (Azeca) tridens.
Clausilia biplicata.
„ rugosa.
Pupa muscorum.
„ marginata.
Vertigo pygmæa.
„ antivertigo.
„ moulinsiana.
Carychium minimum.
Succinea putris.
„ gracilis.

The following remains of Mammalia have been found:

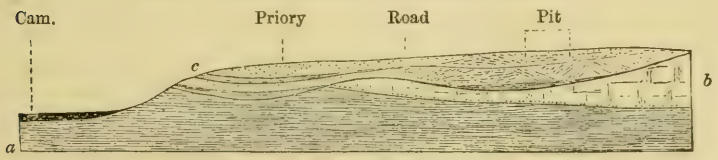
Bos primigenius.
„ longifrons?
Equus fossilis.
Cervus megaceros.
„ sp. (small).
Elephas primigenius.
„ antiquus (rare).
Rhinoceros tichorhinus.
Hippopotamus (major?).
Felis spelæa.

Conspicuous by their presence in the above list are firstly the Mammalian remains which indicate considerable antiquity; *Elephas antiquus* is, I believe, only known by a single tooth, and it has been suggested that this may have been derived from some older gravels; secondly, the occurrence of *Cyrena fluminalis*, *Unio littoralis* and *Hydrobia marginata* must be noted, as they are all now extinct in Britain.

Conspicuous by their absence are *Unio tumidus*, *Neritina fluviatilis*, *Paludina Listeri* and *Lymnæa stagnalis*, since all these are now common in the Cam and its alluvium, associated with most of the other freshwater shells named in the above list; the former two however are generally found in the full strength of the current, while the latter two prefer stagnant marsh pools; but this is hardly sufficient to account for their total absence (even as drifted shells) in the Barnwell sand.

Gravel is found behind the wall of the old Abbey, it is only 7 or 8 feet deep, and is said by the workmen to rest on "clunch" or chalk marl. This is certainly the case in a pit behind the houses on the opposite side of the road to the Abbey Church, whence large quantities of gravel and sand are now being removed, the total depth being about 12 feet; underlying these are one or two feet of marl resting immediately on the clunch from which it has been mainly formed. Clunch comes to the surface on the East, and coprolites are worked at a depth of 20 feet, thus a section through the above pits from N.W. to S.E. would appear as in Fig. 6, for the use of which I am indebted to H. M. Geological Survey.

Fig. 6. Section through the Barnwell gravels.



Horizontal scale 9 in. to a mile; vertical, 100 feet to an inch.

a = Gault. *b* = Chalk. *c* = Gravel.

The gravel may be traced southward to the railway station, where a long section was exposed in 1875, showing beds of

gravel, sand and loam; the depth of these deposits near the goods-sheds is said to be about 16 feet, but opposite the main platform it is not more than 10 or 12 feet, and along the Newmarket line it shallows to 7 feet, and was seen to rest upon an irregular surface of stiff grey marl (probably the Chalk Marl *in situ*, though containing impacted sand and pebbles).

In the cutting near Polecat Farm the gravel is found again and thus caps the highest part of the ridge overlooking the old Cherry Hinton mere; at the time therefore when the river ran at the height indicated by this terrace or ridge, the mere could hardly have been in existence, and its site was probably occupied by ground that sloped upwards toward the Gog-Magog hills of that period, the lower spurs of which have so far receded in the interval between that time and the present, as to allow of the formation of the mere.

The Barnwell terrace is here about half a mile wide, and is separated from the lower terrace on the west by a strip of chalk; southwards the terrace declines gradually towards Brooklands, and the beds have been washed down into the newer gravels, which are here banked against the older series.

The southernmost pit is situated in the angle between the railway and the Hills Road, and shows from ten to six feet of sandy gravel, with a band of marl near the bottom. The ballast pits between the railway and Brookland Farm expose about 8 feet of sand and gravel, resting on Chalk Marl.

Having now described the position, character and contents of the Barnwell gravels, it will be sufficient to trace their continuation southwards.

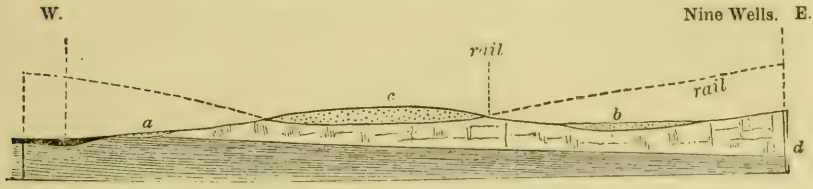
Crossing the shallow valley through which Vicar's Brook now runs, and which we shall find to have been the course of the Cam at a subsequent date, the higher series of gravels are continued by Trumpington; gravel and sand to a depth of 16 or 20 feet underlie the greater part of this village, but thin out towards the church[1].

The railway cutting between the branching roads south of Trumpington intersects this ridge of gravel, which appears to thin out both eastward and westward, for near the 28th mile on

[1] The Rev. O. Fisher informs me that a tooth of *Elephas primigenius* was found in sinking a well at the Vicarage.

the railway, chalk appears in the ditch, and thus the older gravels are probably separated from the newer deposits in the low ground to the east (see Fig. 7, lent by H. M. Geological Survey).

Fig. 7. Section through the Trumpington gravels.



a=lowest terrace. b=second terrace. c=highest terrace. d=chalk.

The gravel pits marked on the ordnance map near Vicarage Farm are ploughed over, and the next section to be found is at the S.W. end of the cutting on the Great Northern line near Shelford. Here soft white sand is exposed, covered in one place with a bed of white marl, shells occur in the former, and are the same as those found at Barnwell.

Cyrena fluminalis.	Helix ericetorum.
Pisidium (amnicum ?).	„ arbustorum.
Bithinia tentaculata.	„ hispida ?
Valvata piscinalis.	

It is difficult to trace this series of gravels any further south, but there is a patch capping the high ground midway between Stapleford and Sawston that may possibly be of the same age, and just north of Sawston the ridge bends eastward towards Babraham, so that some of the higher gravels near Babraham and Abington may belong to the same series. It is no easy matter however to separate this set of gravels from the older series previously described as crossing the country hereabouts, though I think it would be possible to do so if accurate observations were made of the heights of the different patches.

In the main valley of the Cam I can point to no deposits of this age, they have probably all been swept down to lower levels, for reasons given in the first instance.

Neither have I seen any similar terrace of gravel in the valley of the Rhee, which appears to be of later date than any of the other tributary valleys. No beds of gravel occur along the banks of the Rhee from its sources near Ashwell as far down as Barrington, and I am inclined to think that this portion of

the valley had no existence until the Boulder Clay had been entirely removed from this district, and the springs issuing from the base of the Chalk were brought into play. Opposite Barrington the Rhee receives an affluent which comes down from Wardington Bottom, and running through Foulmire passes between Shepreth and Foxton. It will be remembered that when describing the early river-system (p. 47), it was mentioned that this stream had deserted the course which it took in older times by Heydon Grange and the Crowley Hills to Whittlesford, and that it now followed the direction above indicated.

It is impossible to say exactly when this deviation took place, but from the patches of gravel occurring along the course which it now follows, it seems likely to have been a main line of drainage at some period intermediate between the formation of the Whittlesford gravels, and the excavation of the present valley of the Rhee above Barrington.

It may be therefore that the gravels about Foulmire and Foxton were deposited about the same time as those about Barnwell and Trumpington, but on the whole it seems likely that they belong to a somewhat later period.

The valley of the Bourn, on the other hand, appears to have existed from very early times, and remains of the three principal terraces occur along its slopes. The highest of these has been mentioned by Prof. Seeley as forming a ridge between Barton and Grantchester[1], and in all probability this was originally continuous with the Trumpington gravels, from which it is now separated by the modern valley of the Granta.

In the old pits behind Grantchester church about 10 feet of fine gravel and sand was exposed in 1874, and I was informed that large bones and teeth had been found here. From this point the gravels extend westwards and occupy a hollow along the top of the chalk ridge, bearing the same relations to a previous surface as the long gravel-capped ridges previously described.

Beyond Barton the continuity of the series is interrupted by a watercourse draining off the Boulder Clay on Comberton Field, but a large patch again occurs in the upper part of

[1] *Quart. Journ. Geol. Soc.* Vol. xxii. p. 475.

Comberton, and it was from this I presume that the tooth of *Rh. tichorhinus* mentioned by Mr Seeley was obtained.

Beyond this point the terrace cannot be traced, and it has probably been carried away by subsequent denudation into the newer gravels below.

§ *b*. Returning again to Cambridge as the starting point, the gravel which underlies Downing College, New Town and the Botanical Gardens, and presents an evident bank to the river near Mr Bland's farm, is found to stretch up both sides of Vicar's Brook, and to occupy the shallow valley previously mentioned as cutting through the older (Barnwell) series between Brookland Farm and Trumpington Mill (see also Fig. 7). At the cottage where the Mill Road crosses the railway, there is said to be 12 or 15 feet of gravel, and the same material continues to occupy the low ground as far as Shelford, where it may be seen in pits near the bridge over the Cambridge and Hitchin railway; gravel underlies most of Great Shelford and is from 8 to 12 feet deep in various parts of the village, ending abruptly against the river; but on the other side of the alluvium it appears to be continued by Frog Hall to Whittlesford. Beyond this it is not easy to separate it from gravels of later date, and the same may be said of its continuation up the Linton Valley by Howe Field, Babraham and Abington, for gravel is found along the banks of both streams at all levels from the recent alluvium to a height of thirty or forty feet above it.

It would appear, therefore, that at the period in the history of the Cam valley which we have now reached, these united streams did not take their present course by Little Shelford and Hauxton, but ran nearly due north, as far as Cambridge, before they were joined by the Rhee and Bourn.

As regards the Rhee, indeed, we have already shown that it could hardly be said to have any existence; the upper part of its course being so very different from that which it now follows, and the main stream at this time being probably that which descends from Wardington Bottom.

Gravel occurs on the east side of the Rhee, both north and south of Harston, but at no great height above the river, and these patches seem to lead on to a much larger spread of gravel

near Foxton, which keeps away from the present stream and points up the older valley towards Foulmire, so that the gravel occurring near the latter place would appear to belong to the same series.

Along the valley of the Bourn Brook there are several patches of gravel at levels intermediate between the Barton ridge and the more recent beds which flank the present brook. The largest of these is at Toft, another occurs near Lords Bridge, and a third lies midway between Spring Hall and Cantalupe Farm; some of the gravel east of the latter place is much about the same level and may be of the same age, with more recent gravel banked up against it.

The stream in the channel of which these gravels were deposited probably united its waters with those of the Rhee near the junction of the present streams, and the gravel bank extending from Byron's Pool to the vicinity of Trumpington House appears to belong to the same intermediate series.

The gravel which underlies Croft Town and Newnham is at nearly the same relative level, and it must have been somewhere about this locality that the two rivers, which then flowed northwards, one on each side of the Trumpington ridge, met to form the Cam or Granta of that period.

Such appears to have been the aspect of the Cam valley before the time when the river changed its channel for the last time, and took its present course by Little Shelford and Hauxton to join the Rhee near Cantalupe Farm.

§ *c.* The gravels which flank the alluvium of the present river hardly merit any particular description, and it will be sufficient to indicate the principal localities where they occur, especially where they have yielded any fossil remains. It may however be worth while pausing to consider how the last change in the channel, introducing the present state of things, was brought about.

We have seen that the main stream of the Cam, after receiving the Linton brook, continued its northerly course beyond Great Shelford, its western bank being apparently formed by a low ridge of Chalk which stretched across the present site of Little Shelford, and part of which still remains as a narrow strip between the two villages.

This old northward course of the river appears to have been gradually silted up, a bank being probably formed by the gravel brought down from the Linton valley, so that it was slowly converted into a series of marshy pools, remains of which are now discoverable over the surface north of Shelford, where patches of whitish clay overlie the gravel and contain recent shells in abundance, such as are now found in the pools on Sheeps Green.

In the meantime the chalk barrier on the west was gradually overflowed and breached, the initial impulse being probably given during some flood time, and the immediate result appears to have been the production of a lake in the hollow where Hauxton now stands, and the spreading out of gravel over its bottom. For the drainage would at first be blocked by the second ridge of Chalk Marl, which then in all probability extended continuously from Harston to Trumpington, and the waters would be ponded back until they could overflow at Hauxton Bridge; this they ultimately did, and by the deepening of this narrow outlet the lake has been gradually drained.

Such I believe to have been the history of the gravels about Little Shelford and Hauxton, which therefore belong to a somewhat later period than those previously described, and may be classed with the more recent gravel flats.

This lowermost series of gravels is nearly continuous up the valley to Linton, and small pits have been dug here and there. Near Bartlow station there are pits showing about 10 feet of gravel and loam, in which elephant tusks have been found, as well as shells of the genera *Helix*, *Pupa*, *Bithinia*, and *Succinea*.

Along the main valley of the Cam larger spreads of gravel are met with, now on one side of the present channel and now on the other, extending thus for a distance of 13 miles from Shelford to beyond Newport in Essex. The principal pits along this line occur at the following places.

Whittlesford. East of the station, in gravel and sand.

Little Chesterford. A large pit just south of this place exposes about 30 feet of gravel and sand in horizontal layers. Teeth of *Elephas primigenius* have been found here.

Wenden. At pits near the river 15 feet of loamy gravel is shown, from which elephant bones have been extracted.

Newport. Half a mile south of the village is a pit exhibiting sandy brick-earth, underlain by fine light sand, the latter also enclosing mammalian remains.

Passing now to the gravels which stretch northward from Cambridge, we find them spread out over a wide extent of country, bounded on the west by the long ridge of the Girton and Observatory gravels, and on the east by the alluvium of the present river. This sudden wide extension of the gravels may be accounted for in two ways; either it indicates the previous existence of an estuary in which the deposits were spread out, as Prof. Seeley believes; or else it is due to the river having continually cut back its eastern bank, so as to leave a series of undisturbed gravels on its western side.

It is true that the outspread of gravel between Cambridge and Histon has somewhat the appearance of an estuarine arrangement; at least it is difficult to conceive how some of it could ever have been formed in any river channel. It may be however that this is only the result of excessive subsequent denudation, and the area appears to be highest in the centre about Arbury, King's Hedges and Landbeach, the height of the ground between the two latter places being given by Fitton as 55 feet above sea-level; from this central line it slopes evenly and gradually down to the present alluvium on the one side, and irregularly towards Histon on the other, as if there had been some slight local elevation over the intermediate tract.

Again, one would not expect to find a watershed in a plain of river-gravel; but a marshy field between the old semi-circular encampment called Arbury and the main road to Histon appears to occupy such a position, the water soaking off eastward and westward from this spot to supply ditches and streams which flow respectively into the Cam and the Ouse.

It is worth while noting these circumstances, even if they cannot be held to prove any postglacial disturbance of the surface.

The true explanation of this wide spread of gravel is probably to be found in the second alternative, viz. that the river has always had a tendency to encroach upon its eastern bank, and has gradually changed the direction of its course from N.W. to N. and finally to N.E.

The more recent changes of the channel certainly seem to have been in this direction, and the present river, which keeps nearly parallel to the low terrace of gravel stretching away from Chesterton through Milton to Waterbeach, begins to take a more easterly course near the latter place, and has left a strip of Gault-land between the gravels and the alluvium.

I think therefore the westernmost deposits of loam and gravel may safely be taken as the oldest, and those nearer the present river as successively newer; it is possible also to group them in three series, which may be the continuations of the three terraces described as existing in the higher portion of the valley. Thus the gravel which occupies the ground north of Cambridge towards Impington and Histon may be a continuation of the Barnwell series; patches of loam occur in it here and there, but these are not exposed in any pits where a search for shells might be made. About Impington the Gault comes to the surface in many places, and the gravel only occurs in hollows and channels, but north of Histon there is a large patch forming a low plateau which is cut off abruptly along its northern edge; from this a Gault slope leads down to the valley of a little brook or ditch draining into the Ouse.

Gravel is also seen along the Roman road between King's Hedges and Landbeach; indeed the whole country hereabouts seems to have been once covered with gravel, though little more than a gravelly soil now remains to indicate its former presence.

The Chesterton gravel is at a lower level, and forms part of the terrace above mentioned as stretching for some distance to the N.N.E. in a direction nearly parallel to that of the present river; beyond Milton however it bears nearly due north, and passes between Landbeach and Waterbeach towards Goose Farm and Denny Abbey, disappearing finally under the peaty soil of Cottenham Common and Chaff Fen.

There are numerous small gravel pits scattered along this strip of country, but they do not show any good sections, and I did not succeed in finding any organic remains. Prof. Seeley says[1] that he has found shells at Chesterton and other places, "but in every case they were land or freshwater forms, though

[1] *Quart. Journ. Geol. Soc.* xxii. p. 475.

from the gravel of Waterbeach the Woodwardian Museum has the vertebræ of a whale, which from its preservation was evidently contemporaneous with the bed." It would be desirable to know whereabouts in Waterbeach this was found, whether in gravel under alluvium or in the higher series westward of the town, for the village itself is situated mainly on a strip of gault which separates the two sets of gravels. The gravel and sand underlying Waterbeach Fen and bordering the alluvium near Chesterton and Milton are comparable with the low level deposits previously mentioned.

Wilbraham Fens. To enter upon a general description of the Cambridgeshire Fens would be beyond what I understand to be the scope of the subject proposed, and would certainly prolong this Essay to an inordinate length. There is however one isolated tract that merits description here, inasmuch as its origin is connected with that series of ancient river-gravels which form so noteworthy a feature in the vicinity. This is the fenny district which stretches southward from Quy between Wilbraham and Fulbourn, and is known as Wilbraham Fen; its history appears to have been somewhat as follows.

When the drainage of the country was carried off by the ancient river above referred to, this fen could have had no existence, and the springs which now rise near Wilbraham and Fulbourn were then probably at a higher level and contributed their supply to the river itself; but when the drainage ceased to take this course, and the hills were gradually cut back southward, the springs would retire also in that direction, while the old river-course remaining as an elevated ridge prevented the outflow of these waters to the north, and caused the formation of a shallow lake in the same way as the moraine of an old glacier ponds back a mountain stream. The level of this lake would rise until the water overflowed the gravel ridge and made an outlet for itself where Quy-Water Bridge now stands. This outlet having once been made, the lake probably drained itself to a certain extent until it was reduced to the condition of a fen with pools or meres in the deeper portions of the area: in this state it remained until attempts were made to bring it under cultivation, the streams being banked up and carried along in definite channels.

The northern part of the fen however still continued to lie under water, and is remembered as a haunt of wild-fowl by some of the neighbouring villagers.

Peat still remains here, and in patches elsewhere over the area, but in other parts the floor of gravel and sand is exposed, its limits still roughly marking out the extent of the old lake.

Fulbourn Common, Coldham Common and Cherry Hinton Mere, all marshes at one time, were doubtless formed in the same way, the long bank of gravel blocking the drainage and causing an accumulation of water on the southern side.

CHAPTER VII.

CORRELATION OF THE CAMBRIDGESHIRE DRIFTS WITH THOSE OF THE EASTERN COUNTIES.

In correlating the various glacial deposits which occur in different parts of eastern England, the presence of the great Chalky Boulder Clay is of great assistance; from its wide extension and the constancy of its principal characters it forms an excellent base or reference-stratum, so that, the presence of this clay having once been definitely determined, we are at once able to correlate the other members of the series which may exist in the separate areas.

This Boulder Clay, the Upper Glacial of Mr S. V. Wood, Junr., has been mapped both by him and by the Geological Survey over the whole of Essex and over large parts of Cambridge and Suffolk. Its extension through Cambridgeshire has been indicated in the preceding pages, and it has been shown that the main mass of this clay ends along the edge of the Chalk escarpment above Royston, Saffron Walden, Linton, Balsham, and Dullingham, at a height of from 500 to 350 feet above the sea. It has however been pointed out by Mr W. H. Penning[1], that there are occasional outliers sloping down the escarpment into the ancient valley of the Cam, and that the subsequent re-excavation of this valley has resulted in the separation of the Boulder Clay areas lying to the N.W. of the main mass, with which they were once undoubtedly continuous.

Thus the great spread of Boulder Clay which lies on the

[1] *Quart. Journ. Geol. Soc.* Vol. xxxii. p. 198.

high ground between the valleys of the Cam and the Ouse is proved to be of Upper Glacial age not only from the similarity of its constitution and contents, but from general physical considerations deduced from a study of the whole county.

An examination of the heights marked on the ordnance map shows that the basement-level of the clay in this district gradually descends from a height of 250 feet on the south, to that of only 120 on the north. Prolonging this gradual slope, we are not surprised to find that the base of the same clay on the Isle of Ely is only 60 or 70 feet above the sea, and that northward it sinks down below the level of the fens and ultimately below the level of the sea.

This gradual declination of the Upper Boulder Clay at once disposes of the erroneous correlations which Mr Seeley made in 1866; it is now seen that neither the Lower Boulder Clay nor the Contorted Drift are to be found in Cambridgeshire; and not only so, but it is a question whether anything that can be truly called Middle Glacial occurs within the limits of the county.

Mr Searles Wood, Junr., was the first to remark that the Mid-Glacial gravels do not occur above a height of about 300 feet, but he has never spoken of them as limited to the eastern side of the Chalk escarpment, indeed he has mapped them as occurring in Bedfordshire and Huntingdon, as well as beyond the western boundary of the Boulder Clay at Saffron Walden, Dullingham, and Newmarket.

Mr Penning, on the other hand, has seen reason to conclude that they are so limited, and that no such sands or gravels are to be found in the Cambridge valley; it is certain at any rate that most of those so mapped westward of the chalk escarpment are *Post-glacial*, that is to say, posterior in age to the Upper Glacial of Mr S. V. Wood.

Those which are actually seen to lie beneath the Boulder Clay are, I believe, merely local lenticular patches at or near the base of this clay; such intercalated beds of gravel are by no means rare in Suffolk and Essex, and may be seen for instance near Sudbury. This I believe to be the explanation of the series visible near Audley End and described in the early part of this Essay; the sands and loams which here intervene between two similar clays being probably the result of con-

temporaneous current action. The way in which the Boulder Clay runs down into the valley about Newport and Wenden shows that this was a pre-existent hollow; it would therefore form a narrow strait at the first incidence of the Boulder Clay (always supposing this to be a marine deposit); consequently it is only likely that a current would set through the gap and give rise to patches of sand and gravel, interstratifying them with the lower portions of the Boulder Clay itself.

I agree therefore with Mr Penning, that there is no evidence for the existence of Middle Glacial beds in the Cambridge valley, and that the earliest glacial deposit is the Upper Boulder Clay. Mr Searles Wood considers this as the uppermost and latest of the glacial series, and he proposes to class as *Post-glacial* all beds which can be proved to lie unconformably on this clay. It seems to me, however, that it is more reasonable to consider the great chalky Boulder Clay as accumulated during the most intense period of glacial cold, and I do not see why other beds should be excluded from the glacial series simply because they happen to lie above this particular clay.

Supposing, with Mr S. V. Wood, that the glacial beds are of marine origin, and that the Boulder Clay was deposited during the great submergence, surely marine glacial gravels are just as likely to have been formed during the elevation as during the depression of the shore line; it is indeed a well known fact that there are large spreads of gravel above the Boulder Clay which have none of the appearance of ordinary terrestrial gravels, and which have been termed "Plateaux Gravels" by Mr Wood.

I believe them to be in great part the Upper Erratics of Mr Trimmer. Mr Searles Wood however appears to be only acquainted with these Plateaux Gravels in Norfolk; he speaks of them in the following terms[1]: "This gravel is everywhere unfossiliferous and is composed almost entirely of flints. It is difficult in some cases to form an opinion whether it is of glacial or post-glacial age. Most of that shown in sections is doubtless post-glacial, but with respect to that which caps Mousehold Heath it seems the same as the gravel which has an extensive spread in West Norfolk, since, like it, the gravels

[1] Preface to Monograph on Crag Mollusca (Palæont. Society).

of these places contain beds of very large flints more or less rolled. These gravels of West Norfolk set in almost along the same line as that about which the Middle Glacial ceases (from Hingham on the S. to Wells on the N.). They are also composed almost entirely of large flints, which are mostly so rolled as to resemble cannon-shot.

"These cannon-shot gravels sometimes contain masses of sand formed of chalk grains, and as they are never overlain by the chalky clay, but in a few instances have this clay under them, it may be that, if not of post-glacial age, they are a local modification of such clay due to the action of some powerful current over this part of Norfolk, which dissolved all the soluble part of the moranic material forming that clay and rolled the flints into the cannon-shot form.

"The absence of these gravels over the southern part of East Anglia is a peculiar feature, but some beds of gravel on the Wolds about Specton and Bacton seem to bear a similar relation to the Purple Clay of those places."

With respect to the last paragraph above quoted, it is now found that the gravels are not absent over the more southerly parts of East Anglia, but that they extend through West Suffolk into Cambridgeshire, and that they form quite as important a series of deposits as the Middle Glacial beds below. In many parts of Suffolk and Cambridge these gravels closely resemble those of the Middle Glacial, so closely that I think they must have originated under similar circumstances; if therefore the Middle Drift is a marine deposit, then these gravels are probably marine, and they must be taken as forming part of the Glacial Series of East Anglia. I am therefore led to think that it may ultimately be found convenient to group this series into an Upper and Lower Division in the way suggested below, each division having an argillaceous member overlaid by a set of loams, sands and gravels.

1.	Cromer Till and Contorted Drift	Lower Glacial.
2.	Middle Drift	
3.	Chalky Boulder Clay	Upper Glacial.
4.	Plateaux Gravel	

CONCLUSION.

Having in the last chapter endeavoured to correlate such of the glacial deposits in Cambridgeshire as seem comparable to any in other parts of East Anglia, I conclude by offering a few remarks upon two much-contested questions, viz. the conditions under which these beds have been deposited, and the age of the principal physical features of the country.

I cannot but feel that the knowledge of glacial phenomena and glacial formations which I at present possess, although aided by a practical acquaintance with the latter as they are exhibited over parts of Cambridge, Suffolk and Norfolk, is insufficient to enable me to arrive at any very decided conclusions regarding the first of these questions. I cannot regard any of the rival theories as entirely satisfactory, and think that a much larger experience, and a still greater accumulation of facts, is yet needed before this problem can be fully and completely solved.

I shall venture however to criticise certain opinions that have been put forward concerning the stratigraphical relations of some of the beds, and to state some inferences regarding the physical geology of Cambridgeshire which seem to follow from a consideration of the facts recorded in the preceding pages.

At the time of writing this Essay I looked upon the main features of the country as determined before the Glacial Period; some of them were demonstrably in existence before the incidence of the Upper Boulder Clay, and it was equally evident that most of the minor features were produced at a subsequent date. I saw no grounds for supposing that there was any marked break in the glacial series, but was disposed to agree with Mr Penning, that, in the succession and transgressive

extension of these deposits, we had the evidence of a gradually deepening marine area, open to the north, with land on the south and west. I believed, moreover, that the Norfolk Lower Glacial was a local deposit containing Scandinavian drift from the N.E. and accumulated before the cold became great enough to cause the formation of ice near the sea level in Britain, but that as the land sank and the cold increased, bergs and coast-ice from British shores supplied the detritus found in the superior and wider-spread deposits.

Messrs Wood and Harmer however have lately published a long paper in which they discuss these questions, and put forward two important considerations[1]; (1) that the Contorted Drift, which they class with the Lower Glacial, had a much wider southward extension than previously supposed; (2) that a marked unconformity exists between the Lower and the Middle Glacial deposits, the break being of such extent and importance that all the valley systems of East Anglia had their inception in the intermediate period.

Suggestive as the whole paper is, I cannot consider that the evidence for either of these propositions is at all satisfactory. The identification of the Suffolk brick-earths with the Contorted Drift is by no means certain; and the section mainly relied on to show the unconformity between this deposit and the Middle Glacial, viz. that along the coast of Norfolk, is, to say the least, capable of a different interpretation. The conclusion to which I came after a careful inspection of it was that the gravels formed part of the contortions, and were closely connected with the beds below instead of being separated from them by a marked line of erosion and denudation[2].

The last few pages of the paper are devoted to a consideration of the mode in which the Middle and Upper Glacial beds are accumulated; the authors conjecture that a branch of the ice-sheet, moving southwards from Yorkshire and Lincolnshire, and being of great thickness (1200 to 1500 feet), occupied all the low ground of the midland counties as far south as Bucks, "in such a way that it avoided all but the extreme west of

[1] *Quart. Journ. Geol. Soc.* Vol. XXXIII. p. 74.

[2] My colleague, Mr C. Reid, informs me that his survey of the Cromer coast has led him to take the same view.

Norfolk and Suffolk," which counties were submerged to an extent of 400 feet below their present level. They think that the Middle Glacial was kept out of this midland area by the presence of the ice-sheet, and that it was only accumulated beyond the limit of the land-ice by the currents which washed its edge.

All this, however, is so purely conjectural, and though it might account for some of the facts, yet it seems to create difficulties so much graver than those which the authors seek to explain, that it is impossible to take it as representing, with any degree of probability, the actual physical conditions of the period.

Admitting therefore that at present we cannot hope to account for all the phenomena presented by the glacial deposits, I am still inclined to think that a modification of the older theory, and the supposition of a gradually increasing submergence from the date of the Forest Bed, offers the fewest difficulties in explanation of their mode of occurrence.

In this connection I would call attention to the claims of coast-ice, recently advocated by Prof. J. Milne, to be regarded as an important agent in glaciation. Such ice operates in less depth of water than berg-ice, and is found to carry much greater quantities of material; moreover it is capable of explaining the local character which the Boulder Clay almost everywhere exhibits, and which has been thought a fatal objection to the marine theory.

Such a gradual submergence does not of course preclude the possibility of there having been minor oscillations of level, and changes in the amount of cold during the whole general period; but it would appear that the deposition of the Chalky Boulder Clay marks the maximum both of depth and cold, and that the land then gradually rose again from out of the glacial sea.

Starting therefore with the supposition that at this time the whole of Cambridgeshire was deeply submerged, let us consider what would be the result of its gradual re-elevation. It is clear that the clay-covered escarpment of the Chalk would first rise as a low ridge, and would be subjected to the action of marine currents; these would sift and re-arrange the Boulder Clay, forming deposits of gravel such as exist eastward, northward and westward of the highest portions of the scarp.

As the land continued to rise and increase in extent, rain would fall upon its surface, perhaps in greater quantity than at present; streams and rivers would come into existence, still further arranging both the Boulder Clay and the coast-gravels previously formed; and these rivers would have a general tendency to flow from the dominant ridge towards the N.W. and S.E., the northerly tendency being increased in Cambridgeshire by the slope of the country towards the estuary of the Wash, which was in existence before the incidence of the Upper Glacial Clay.

Taking the above as an outline of what would probably happen during such an emergence of East Anglia as was initially supposed, it is satisfactory to note that all the deposits described in this Essay are fully accounted for by such a series of events, and that their relations to one another are perfectly explicable on this hypothesis.

The "Hill gravels" and their probable equivalents, the "Plateaux" or "Flood gravels," seem to have been accumulated rapidly, and like the Middle Glacial sand and gravels they are apparently marine; yet so closely are they connected with a second set of gravels which are clearly of fluviatile origin, that no long period of time can have intervened between the formation of the two series; the conditions which caused the production of the former seem also to have led to the formation of the latter, and from this time to the present there is no reason for supposing that East Anglia has been subjected to any other influences than those of rain and rivers.

Turning now to a consideration of the changes that have taken place since the emergence of the country from the glacial sea, the evidence afforded by the series of ancient river gravels leads to some interesting results.

It is indeed a significant fact that in these higher districts the gravels have a recognisable relation to the existing valleys, while when they emerge upon the plain country all such connection is lost, and the direction which they take across the country is quite irrespective of the present river system.

We may at once conclude that the outline of the hill country has not changed so much as that of the plain, and that its present valleys are but the more deeply excavated termina-

tions of the old valleys which these ancient rivers had formed and which were once continued across the country; their lower prolongations, however, have since been entirely destroyed, and instead of valleys long ridges only now remain, cut through at various points by channels of more recent origin. Such a result might indeed have been anticipated, since water flowing down a steep slope and cutting a deep groove for itself must tend to keep approximately in the same channel for a longer period of time than when it reaches lower and more level ground, where very slight changes are sufficient to produce great deviations in its course. Still it is none the less interesting to find the result so clearly stereotyped on the country as it is by this series of gravels, which enables us to estimate roughly the enormous amount of denudation which has taken place since the time when they formed valley bottoms instead of elevated ridges.

We see therefore that while little change seems to have taken place in the higher parts of the old valleys, where the watercourses still preserve their original directions, and patches even of the primeval mantle of Boulder Clay still remain upon the bounding heights; great changes have gone on outside the hill district, resulting in the removal of much material, and causing many important alterations in the direction of the main rivers.

The whole succession of post-glacial valley gravels seems indeed to have been singularly well preserved in this part of England, and if the various beds could be thoroughly disentangled, they would mark out the courses of the streams at different times, and present us with a picture of the successive changes which have taken place in the river system from the glacial period to the present time. Without attempting to give such a history of the manner in which Cambridgeshire was moulded, I think the following statements regarding the relative age of its principal physical features are warranted by the evidence which has been brought forward.

(1) That the great hollow of the north fens existed to a great extent before the incidence of the Upper Boulder Clay; but that of the south fens between Ely, Newmarket, and Cambridge had no such existence, having on the contrary been formed subsequently to the removal of the Boulder Clay.

(2) That the valley of the Cam above Whittlesford and its tributary valley through Linton are the oldest channels in the district, dating from a time anterior to the formation of the Chalky Boulder Clay.

(3) That the valleys radiating from the Chalk escarpment had their inception in early post-glacial times, when the drainage system was entirely different from that of the present rivers.

(4) That the first determination of the waters towards the present system is marked by the series to which the Barnwell gravels belong; that the gravel-filled hollow between Shelford and Cambridge marks an intermediate stage; and lastly that the present valley of the Rhee and Granta is the newest of all, and that its direction is nearly at right angles to the earliest lines of drainage.

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